

Civil Engineering and Geodesy

December 2001

Title:

Civil Engineering and Geodesy

Series: Assessment of Research Quality

Utrecht: VSNU, year 2001, 73 pages (including appendices)

Code: PU/130342

ISBN 90-5588-377-8

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Foreword

It is with great pride that I herewith present this report on the research in Civil Engineering and Geodesy. It is one of the reports in the second round of evaluation of research quality in which international committees of independent experts are assessing all University research per discipline.

The Review Committee for the assessment of research in Civil Engineering and Geodesy has fulfilled its tasks with great dedication. Twenty-six research programmes from two universities (Delft and Twente) were evaluated in a thorough and careful manner. I expect the judgements and recommendations will be taken into careful consideration by research directors, faculty boards and research policymakers in the field of Civil Engineering and Geodesy.

I thank the Chairman and Members of the Review Committee for Civil Engineering and Geodesy for their willingness to participate in this assessment and for the dedication with which they carried out this task. I also thank all deans of faculties and programme directors involved for their carefully prepared documentation and for their co-operation during the assessments.

E.M. d'Hondt
President of the Association of Universities in The Netherlands

Preface

The Review Committee Civil Engineering and Geodesy was entrusted with the task of evaluating the research of the Departments of Civil Engineering and Geodesy of the Faculty of Civil Engineering and Geosciences of Delft University of Technology and the research programme Civil Engineering & Management of the Faculty Technology & Management of the University of Twente over the period 1995-1999. Nine experts from five countries, covering the various disciplines in question, were invited to compose the Review Committee, assisted by two secretaries. The assessment of the Review Committee is based upon information on research input and output as supplied by the departments, key publications, interviews with the programme directors, visits to laboratories and meetings with the faculty boards. Before finalising the report a draft was submitted to the faculty boards for comments. As this is the second review of civil engineering and geodesy it may be considered as a follow-up on the previous assessment.

The Review Committee is pleased to report that the majority of the programmes meet an international standard and make worthwhile contributions to the international research community. It should also be observed that the research contributes substantially to technology development in the respective fields and to education.

The Review Committee would like to thank the faculties for their thorough preparation of the review of their research, their hospitality and the stimulating discussions during the site visits. Also the secretarial support in the organisation of accommodation and in preparing the report is acknowledged. The members of the Review Committee are pleased to have participated as a team in this research assessment, simultaneously mirroring their own research activities against the programmes in Delft and Twente. Finally the Review Committee hopes that the review will contribute to the continuation of the prominent international role played by the Netherlands in Civil Engineering and Geodesy.

Jelle Witteveen
Chairman of the Review Committee

Summary and Recommendations

The Review Committee is of the opinion that, on the basis of the programmes reviewed and collateral knowledge, research in Civil Engineering and Geodesy in the Netherlands is “alive and well”. The Netherlands remains one of the leading countries in both fields.

The programmes reviewed by the Review Committee are concerned with a whole series of topics, which according to the discipline protocol are grouped into six sub-disciplines. The results of the review, including some significant recommendations, are summarised.

Building Engineering and Management

The overall scores for the submitted programmes in Building Engineering and Management are standard. One programme however does not meet an international standard. The quality and the international orientation of the research can be improved by inviting guest researchers from well known international groups. The recent AWT Foresight report has placed considerable emphasis on the development of research in the field of the building process, particularly in construction management. Therefore there is an urgent need to consider specific initiatives to facilitate a larger and more vibrant university-based research community in building engineering, design and management. The Review Committee recommends that this should also include research in other relevant institutes in the Netherlands.

Code	Research Programme	Q ¹	P	R	V
TUD 01	Building Engineering	3	3	3	3
TUD 02	Civil Engineering Informatics	4	3	3	3
TUD 03	Design and Construction Management	3	2	3	3
UT 01	Construction Engineering and Management	2	2	3	2

¹ For a legenda see Appendix 3

Hydraulic and Geotechnical Engineering

The overall scores for the submitted programmes in Hydraulic and Geotechnical Engineering are good to excellent. The programme on Fluid Mechanics belongs to the top world wide. Based on vital national needs a research and professional expertise have been developed which have received international recognition as well as applications. As a complement to theoretical work, laboratory facilities are of paramount importance. The Review Committee endorses the continuous upgrade of equipment. As in this research area vital vacancies arise shortly, great emphasis has to be given to timely appointment of professors with eminent research ability and breadth of vision to provide appropriate leadership.

Code	Research Programme	Q	P	R	V
TUD 04	Fluid Mechanics	5	5	5	5
TUD 05	Geotechnical Engineering	4	4	4	4
TUD 06	Hydraulic Engineering	5	4	5	4
UT 02	Integrated Modelling of Civil Engineering Systems	4	4	4	3

Infrastructure

The overall scores of three out of four programmes on Infrastructure are good to excellent. In addition to a strong programme in the physical aspects of the infrastructure, particularly in road pavement materials and in railway infrastructure, world class cross-disciplinary research is taking place in the fundamental aspects of traffic systems and in the management of multi-modal urban transport systems. One group in this field belongs to the top world wide.

The programme on Infrastructure Planning does not meet an international standard. It appears that the group neglects the opportunity to build on more fundamental principles as well as to generate general applicability from their context oriented research. As presently a viable vision to enhance the international competitiveness is not visible consideration should be given to the relationship between this programme and other programmes involved with planning issues.

Code	Research Programme	Q	P	R	V
TUD 07	Infrastructure Planning	2	2	2	2
TUD 08	Road and Railway Engineering	4	4	4	4
TUD 09	Transportation Planning and Traffic Engineering	5	5	5	5
UT 03	Transportation Engineering and Management	4	3	4	4

Mechanics, Materials and Structures

The strength of the research on Mechanics, Materials and Structures is rated as very high in all aspects. The work has a significant impact on the international research community in the field. The programme on Structural Mechanics belongs to the top world wide. In view of its relevance to the Dutch society the programme on Wind Energy and Offshore Technology should be strengthened. In this area laboratory facilities remain of great importance and the Review Committee recommends that capital investment in new equipment be maintained.

Code	Research Programme	Q	P	R	V
TUD 10	Concrete Structures	4	4	4	5
TUD 11	Material Science	4	4	4	4
TUD 12	Steel and Timber Structures	4	4	4	4
TUD 13	Structural Mechanics	5	5	5	5
TUD 14	Wind Energy and Offshore Technology	3	3	4	4

Water Management

The importance of this subject to the Dutch as well as to the international society is continuously increasing. The overall scores for the submitted programmes on Water Management are good. The Review Committee however believes that when more attention is given to a focussed, highly collaborative research effort including more PhD students and a higher commitment of faculty time to research there is a potential to reach a world class level.

Code	Research Programme	Q	P	R	V
TUD 15	Hydrology and Ecology	4	3	3	4
TUD 16	Land and Water Management	4	4	4	4
TUD 17	Sanitary Engineering	4	5	4	4
UT 04	Water Resources Management	4	4	4	4

Geodesy

Four out of five programmes within Geodesy are rated standard to good. The programme on Mathematical Geodesy and Positioning is rated excellent in all aspects and belongs to the international top. The Review Committee recommends that more attention should be given to the implementation of Internet and multi-media technologies in general and its use in GIS applications in particular.

Code	Research Programme	Q	P	R	V
TUD 18	Physical, Geometric and Space Geodesy	4	3	4	4
TUD 19	Mathematical Geodesy and Positioning	5	5	5	5
TUD 20	Photogrammatry and Remote Sensing	3	3	3	4
TUD 21	GIS Technology	3	3	3	4
TUD 22	Geo-Information and Land Development	3	3	3	4

In conclusion, the Review Committee recommends that appropriate efforts should be exerted to preserve and further enhance the prominent international role played by the Netherlands in Civil Engineering and Geodesy research. It urges the funding bodies to maintain and, if possible, to increase their support for this essential research area.

1 Introduction

1.1 The Dutch System for Quality Assessment of Research

The quality assessment of research of Civil Engineering and Geodesy is part of the assessment system for all Dutch University research, under the aegis of the Association of Universities in the Netherlands (VSNU). The system started in 1993, with trial-assessments by four international committees in four very different disciplines: biology, historical and archaeological studies, mechanical engineering and psychology. The observations of these committees have been used by the Dutch universities to enhance the system, whose general principles and procedures were described in the *1994 Protocol for the Quality Assessment of Research*. From 1993 until 1997 all University research, per discipline or scientific area, was assessed by means of peer review (international committees of experts within a certain discipline) according to this protocol. In 1997, when nearly all areas had been assessed, the VSNU Committee on the Future of Quality Assessment evaluated the system. As a result of this Committee's advice the VSNU Board decided to have the first round of VSNU research quality assessment followed by another round. Again the general principles and procedures, with a number of changes in comparison with the first round, were described in a protocol (*Protocol 1998*).

The assessment of research in Civil Engineering and Geodesy, which is described in this report, is one of the first assessments carried out according to the new protocol. The most important changes are:

- a greater emphasis on the context-specific aspects of research programmes and faculty or institute missions;
- a more precise application of the criteria academic quality, productivity, relevance, and viability in the light of the mission of a group, faculty or institute;
- the use of nomenclature and definitions according to the VSNU brochure *Definitie-afspraken wetenschappelijk onderzoek* (VSNU, 1994).

As in the first round, the most important functions still are quality assurance (improvement of University research quality as a result of self-regulation within universities, faculties or research institutes), accountability and the collection of information that can be considered relevant to third parties.

The aims of the assessment system are:

- assessment of the quality of research programmes (groups) on the basis of self-evaluations and appraisal of how the work is related to the group's mission, as well as to the mission of the faculty or the institute of which the group's programme is a part;
- evaluation of the mission of faculties or institutes, as well as the group's own mission;
- appraisal of the state-of-the-art in the discipline or academic area concerned.

This means that the assessment takes place at the aggregate level of research programmes. Faculties or research institutes submit a description of the results that have been achieved in each research programme during the previous five years (including quantitative data about staff input, five key publications and a list of publications), a short outline of the ‘mission’ statement of every programme, and developments anticipated in the context of the research profile of the faculty or institute. The mission statement has to contain elements such as: the scope of the research, the nature of the research in terms of pure versus applied, the general approach of the research in terms of mono-disciplinary, multidisciplinary or interdisciplinary, and the principal source of inspiration (curiosity-driven or society-driven). It should also say something about goals and objectives, give an indication of the local identity (for example, its place in a research school), and a description of the relevance of the work to the different audiences. Highly valued features of the assessments are the interviews, which the review committee conducts with delegations of the faculty boards, the directors of the research institutes or research schools, and the programme directors. The interviews with the delegation of the faculty boards are especially aimed at a discussion of the faculty’s research profile, being the result of a faculty’s research policy.

1.2 The Review Committee for Civil Engineering and Geodesy

The Review Committee – henceforth ‘the Committee’ – was appointed on 11 December 2000 and consisted of:

- Professor J. Witteveen, TNO Building and Construction Research and Delft University of Technology (retired), Chairman
- Professor D. Fritsch, University of Stuttgart, Geodesy
- Professor P. Holmes, Imperial College, Hydraulic and Geotechnical Engineering
- Professor A. Krijgsman, Delft University of Technology (retired), Building Engineering
- Professor P. Lansley, University of Reading, Management
- Professor D.P. Loucks, Cornell University, Water Management
- Professor H.S. Mahmassani, The University of Texas at Austin, Infrastructure
- Professor H. Mang, Vienna University of Technology, Mechanics, Materials and Structures
- Professor H. Sünkel, Graz University of Technology, Geodesy

Dr F.A.J. van Steijn and drs D.A.L.E. de Vries, VSNU, were appointed as secretaries of the Committee.

A short curriculum vitae of each of the members is included in Appendix 4.

1.3 Scope of the Assessment

The Committee was asked to operate according to the earlier mentioned Protocol 1998. For the assessment of Civil Engineering and Geodesy, this protocol was elaborated in the Discipline Protocol Civil Engineering and Geodesy, prepared by the Discipline Committee Science and Technology. In this discipline protocol (see Appendix 1) it is mentioned that the assessment covers the whole field of Civil Engineering and Geodesy. On the bases of the required expertise defined in the discipline protocol the Committee divided the field into seven areas:

- Building Engineering and Management
- Hydraulic and Geotechnical Engineering
- Infrastructure
- Mechanics, Materials and Structures
- Water Management
- Geodesy

1.4 Data provided to the Committee

The Committee has received the following documentation:

- Three self-evaluation reports (Civil Engineering TUD and UT and Geodesy TUD), containing a research profile and the key-data of the faculties concerned and documentation per programme;
- Five key-publications per programme.

1.5 Procedures followed by the Committee

The review of the Committee covered a total of twenty six programmes. TUD submitted seventeen programmes in Civil Engineering and five in Geodesy. UT submitted four programmes in Civil Engineering.

The Committee started its review by reading the self-evaluation reports and the key-publications. For each research programme a first and second reviewer were selected. They were asked to read all information in detail and to assess the programmes with the help of a preliminary assessment form (see Appendix 2). The assessment forms were collected as input for the meetings of the Committee with the programme directors during the site visits in the third week of January 2001.

During the first meeting, consensus was reached on a first approximation of the scores. The Committee also prepared a list of questions to be asked by Committee members to programme directors. During the site visits, the Committee met the programme directors, the faculty boards and a number of PhD students. Furthermore the Committee visited the laboratories and

experimental facilities. During the final meeting, the Committee composed a first draft of its report. Soon thereafter the chairman of the Committee informed the faculty boards in general term about the main findings of the Committee.

1.6 Aspects and Assessment Scale

The Committee was required to judge four aspects: quality, productivity, relevance and viability. A five-point scale was used to give scores on the four criteria and an additional commentary was added for each research programme. These commentaries are an integral part of the assessments. Protocol 1998 allows the Committee considerable freedom to interpret the four aspects and the assessment scale in such a way that the assessments reflect what the Committee members see as important. The Committee was thus able to take into account the different characters of the various research programmes under scrutiny. In the case of this assessment, the criteria were interpreted as indicated below.

Quality

The scientific quality of a research group is based on:

- the contributions made to international scientific research and development;
- the standing of scientific publications;
- the originality of approaches and ideas in tackling scientific problems;
- indicators of international recognition other than publications, such as positions in international scientific networks and advisory appointments based on scientific reputation.

The ratings on the five-point scale for quality are defined as follows:

- Excellent (5):** The research group belongs to the international elite within its field of research. It works at the frontiers of international progress in its field and contributes effectively to that progress by means of substantial publications in highly rated scientific journals. World-class.
- Good (4):** The group meets the international standards in its field of research and it makes worthwhile and recognised contributions to the international research community.
- Standard (3):** The group meets the international standards in its field of research at an acceptable level and its contributions to knowledge are of satisfactory quality.
- Below standard (2):** The group does not meet the international standards in its field; it needs some improvement to contribute significantly.
- Poor (1):** The group is far from meeting international standards in its field and has no influence upon its development. A reorientation is needed before the group can be expected to contribute.

Productivity

The scientific productivity of a research group is based on:

- its contribution to the international scientific literature by means of publications in international, refereed journals and scientific books;
- the number of PhD theses;
- its contribution to presentations at and proceedings of international conferences;
- other scientific output, such as professional publications, designs, design tools and methods, software and patents.

The Committee's assessments are based on the production of each research group with reference to its size and resources with relatively more emphasis on scientific publications, including PhD theses, than on conference proceedings and professional publications. Also taken into account are the quality of the journals and the relevance of the publication media to the field of research. The result therefore is a 'peer review' about productivity, which reflects the Committee's perception of the programme's productivity over the past five-year period.

Taking into account the size and resources of the group, the ratings used for scientific productivity are:

Excellent (5)

Good (4)

Standard (3)

Below standard (2)

Poor (1)

Relevance

The Committee has considered the following aspects as part of its integrated assessment of relevance:

- the significance of the contribution of a research group to the development of its field with special focus on originality of ideas and approaches;
- potential impact and applications in future technologies and to meet expected needs;
- the contribution of the research group to relevant scientific and professional networks of (future) users (government, agencies, industry and others) based on its specific knowledge and expertise;
- success in obtaining funding from the second and third sources of funds.

The ratings for relevance are:

Excellent (5)

Good (4)

Standard (3)

Below standard (2)

Poor (1)

Viability

The following aspects are taken into account:

- the continued relevance of the research topics, based on the group's vision and plans for the future (scientific prospects);
- prospects of future funding of personnel and facilities;
- continuity of leadership for the programme;
- coherence of the programme;
- strength of existing linkages and proposed linkages with appropriate University national and international collaborators.

The group's mission statement and plans are judged against the feasibility of developing or sustaining their research. Indications and plans for continuity of leadership at a high academic level are seen as a major aspect of the viability of a programme.

The ratings used for viability are:

Excellent (5)

Good (4)

Standard (3)

Below standard (2)

Poor (1)

2 Research in Civil Engineering and Geodesy in the Netherlands

2.1 General Remarks

Although the Committee was impressed with some of the programmes and quite satisfied with most of the others, it was concerned about a number of recurring issues. Sometimes these represented major constraints on a programme whilst in other instances they took the form of early warning signs. Although these issues are cited in the individual programme reviews, an opportunity is taken here to provide a more reflective account of their nature and their implications.

2.1.1 Staffing issues

A frequent issue was that some programme directors spent very little time, in one case no time at all, directing their programmes. This was largely because of administrative duties and high teaching loads. In other instances experienced and talented staff within the programmes had so little time available for research that they were neither able to develop their fields of interest nor provide the leadership expected of them by junior staff. The opportunity to exploit the leverage provided by the availability of funds to employ research staff and doctoral students was not used, because personal research activity was minimal and below the threshold of viability.

In some cases, the problem of senior staff being so heavily engaged in administration and teaching was further exacerbated by the presence of an increasing number of part-time professors. There are many very positive reasons for employing part-time faculty members, not least the benefits which this brings by keeping a university close to industry or, in some cases, linked to private sector or government research institutes. However, even when judged in a proportionate way, part-time staff tend not to engage heavily in research, nor do they bear key administrative burdens. In turn this can lead to disproportionate loads on full-time staff. A further factor constraining the amount of time which some staff devoted to research, mentioned by several programme leaders, was that staff vacancies were becoming harder to fill. In some instances the vacancies had proved impossible to fill. This was especially true of vacancies in management related programmes although the problem was cited in other programme areas. There were also widespread concerns about the difficulty of recruiting doctoral students, partly because presently there are highly remunerative job opportunities available in the industry but also because a research or academic career was thought to have much less appeal to bright young graduates than in the past.

The effect of these factors has led some programmes, especially those with small numbers of staff, to become vulnerable to changes in their staffing levels. They do not have the critical mass to be able to withstand the

vagaries of the loss of staff followed by prolonged periods before replacement or the flexibility to be able to cope with changes in the mix of staff. These concerns led the Committee to consider seriously the amalgamation of some programmes. These are discussed later in this report.

2.1.2 Nature and Culture of Research

However, other issues also had a bearing on this recommendation, although in essence these relate to the issue of the size of the programmes.

As research has become more interdisciplinary, applied and generally user-orientated, so it has become more difficult to maintain the narrow focus on which many programmes were built. There is a need to engage more disciplines and skills and inevitably this leads to the need for larger more comprehensive programmes. Whilst this issue was identified in several programmes, it was most obvious for some of those programmes which combine elements of the social sciences with those of the sciences, often in the guise of management or planning related research.

In these areas some programmes were considered to be too small. This would have been the case even if some of the staff within these programmes were less constrained by administrative and teaching duties and more involved with research.

The Committee was exercised by the situation of some of the programmes. For example, in particular construction management programmes were adversely affected by the issues outlined above, as well as by a “lack of fit” between the culture of management research and an academic environment in which a traditional culture of civil engineering research tends to prevail. Further, there was a concern that whilst some individuals within these programmes were undertaking work of the highest international standard and their work was recognised by industry as well as by other researchers, the programmes were not. The traditional academic value system of “independence and excellence” is commendable, but in these areas it does not provide a foundation for developing viable programmes. However, in the absence of special initiatives to stimulate and develop work in these areas, including increasing the capacity of universities to engage in work of this kind, the programmes are unlikely to develop substantially from their present modest levels. As a first step, there is a strong case for combining programmes within faculties, across faculties, and possibly across organisations although appropriate co-ordination mechanisms would need to be put into place.

Whilst programmes which are inherently interdisciplinary and in which social science paradigms make an important contribution tended to achieve modest ratings, so too did some programmes which operated within

the well established research traditions of civil engineering. For these it is more difficult to generalise. There are no obvious common factors which underlie their modest performance. Rather these are best considered in terms of the normal competitive factors which influence traditional science and which are discussed in the sections on each programme.

Furthermore the Committee noted that care must be exercised in evaluating journal publications in multi- or cross-disciplinary research programmes because of the limited number of journals that deal with these kinds of topics. There is obviously a high potential for multi-disciplinary research but it is not an easy area in which original progress can be made – partially because of a paucity of potential PhD candidates for research in an environment to which they cannot readily adapt if educated in a relatively mono-disciplinary manner.

2.1.3 Serving Societal Needs

The Committee noted the well-developed linkages between several programmes and the needs of society and industry. Within university programmes a balance has to be struck between research which is orientated towards application for the benefit of society and that which is more fundamental and focused on the generation of new scientific knowledge. Generally those programmes which had achieved this balance, for example those with grants from the NWO Technology Foundation (STW), were quite able to link academic outputs to practical applications and technology development. Overall these achieved better grades than those which were either strongly orientated towards one or other type of work.

Some programmes appeared to have been encouraged towards external support, primarily consisting of funding for contract research. However, this did not appear to lead to research which was judged to be of or near to an international standard. At a time when national research priorities are changing, especially in the light of, say, the AWT Foresight report, there is a need to ensure that programmes are able to access a range of funding routes. Such an infrastructure might well assist in ensuring that society and industry can gain most from high quality academic work.

2.1.4 More Information

Research programmes produce many different types of output. One of the most valuable is highly trained manpower in the form of doctoral graduates. The difficulties experienced by some programmes in recruiting doctoral students was noted earlier, yet increasingly industry, government and universities need such graduates, not just for research but to provide leadership in the mainstream activities of industry, government and, more generally, society. The VSNU protocol does not require provision of information about the career paths of recent doctoral graduates, yet in applied fields such as Civil Engineering and Geodesy, such information would have been valuable. It is recommended that such information should be provided for subsequent Panels. Whilst recognising that the outcome of the Review strongly endorses the quality and orientation of Civil

Engineering and Geodesy research, the issues discussed above, principally manpower, organisation and funding, indicate a number of developments which, unless addressed, in the longer term could have an adverse effect on the quality of research in the Netherlands.

2.2 Disciplines

2.2.1 *Building Engineering and Management*

Traditionally the Netherlands has enjoyed a leading position in building engineering research and design and management research, facilitated by the work of dedicated research institutes, some academics and the regular participation of industry in research programmes. However, university based activities in these fields lack a critical mass. Small groups are distributed, sometimes uncomfortably, between civil engineering and architectural faculties, often with very high teaching loads. Those with achievable missions often have a narrow focus. They undertake valuable work but have difficulty finding the resources to integrate their work with that of others. Those with broader missions do not have the capability to develop an integrated understanding of contemporary issues in design, engineering, IT, management and business or to establish sustainable long-term research programmes. Yet this is exactly what is required if research is to meet the needs of industry and society and key issues are to be addressed, such as those highlighted in the recent AWT Foresight report.

The level of interdisciplinary working required of these fields necessitates quite large research groups. Nevertheless, despite these shortcomings, there are some very able academics undertaking valuable research and others in related areas who could be usefully directed towards these fields.

In the light of this assessment of Civil Engineering and Geodesy and that of Architecture, Building and Planning in 1998, there is an urgent need to consider specific initiatives to facilitate a larger and more vibrant university-based research community in the fields of building engineering, design and management. This is necessary to meet national needs as well as to strengthen the international standing of Dutch research in these fields.

2.2.2 *Hydraulic and Geotechnical Engineering*

There is a very long tradition of Hydraulic and Geotechnical Engineering in the Netherlands, more recently enhanced in quantity and quality following the catastrophic inundation of 1953 and the admirable Delta Project. This context encouraged both research and applications in the field, embedded in the University sector and in the institutes Delft Hydraulics and GeoDelft. These two parallel modes of development have remained in close contact by virtue of the almost daily interaction between top-level academic researchers and outstanding practitioners. This has resulted in this sector of the Civil Engineering profession taking a lead world-wide in important applications areas, including that of dredging.

The close interaction between the University sector and world-class professional organisations very much rooted in the Netherlands has maintained and extended cross-fertilisation. There now exists a context of generic research influenced by a clear awareness of practical implications – but not overly conditioned by that awareness. There also exist research programmes somewhat more applied in nature but firmly rooted in the understanding of complex, core physical processes. The maintenance of this enviable balance is much to the credit of present senior academic staff and their predecessors. It is a balance of primary importance and its continuation must be of the highest priority.

Thus, based on vital national needs over half a century or more, a research and a professional expertise have been developed which has found ready recognition and applications internationally. A more recent evolution in this area is the need to build understanding and numerical modelling capabilities at space and time scales larger than previously but still founded on valid core physics. Added to this is the requirement to include chemical and bacteriological parameters, and extensions into socio-economic fields.

It is essential that in these developments the preservation and enhancement of the links between generic and applied research, and those between these and the broader ‘systems’ modelling, should be preserved.

The contributions to society of this long-established research tradition are obvious in terms of safety (inundation risks) and environmental quality. The latter include not only the obvious environmental factors but also less tangible aspects such as the recreational assets of lakes, beaches and coastline.

There is no doubt whatsoever that the research investment in people and facilities has been cost-effective by any standards, at both national and international levels.

2.2.3 Infrastructure

The area of civil infrastructure research addresses systems that are critical to the quality of life and economic vitality of a country. Academic research in civil infrastructure in the Netherlands is primarily focused on the Transportation sector, though a common set of approaches and methodologies for the planning, evaluation, operation, management and renewal of infrastructure systems in general are now emerging. The transport infrastructure system is clearly of utmost importance to the Netherlands, which is a major transport hub and gateway for Europe. Infrastructure systems research has evolved considerably over the past four decades, and has become increasingly cross-disciplinary in character. In addition to expertise in the Civil Engineering discipline, Transportation infrastructure systems research draws on economics, operations research, information technologies, statistical methods and the social sciences. This is a reflection of the complex nature of these systems, which involve interaction among multiple agents in a man-machine environment.

The research programmes at TUD and UT reflect the changing character of the infrastructure systems area. In addition to strong programmes in the physical aspects of the infrastructure, particularly in road pavement materials and performance and in railway infrastructure (at TUD), world-class cross-disciplinary research is taking place in the fundamental aspects of traffic system behaviour, and in the management of multimodal urban transport systems. In particular, the potential of new information and communication technologies on traveller behaviour and system performance is well recognised and represented in the programmes the Committee reviewed.

The infrastructure systems area in general is likely to continue as a major opportunity area for the application of emerging technologies in the areas of sensing, telecommunications, computing, online decision systems. The programmes at TUD and UT appear quite well positioned to participate and play a leading role in the development of the scientific and methodological core knowledge necessary to realise this potential.

2.2.4 Mechanics, Materials and Structures

At TUD, the area of mechanics, materials and structures is represented by the following five programmes: Concrete Structures, Materials Science, Steel and Timber Structures, Structural Mechanics, and Wind Energy and Offshore Technology. The strength of this area both with regards to quality and quantity of scientific output is rated as very high. The work of this group has a significant impact on the international research community in the field. The programme in Structural Mechanics meets the criteria of academic centres of excellence. It certainly belongs to the top world-wide.

In relation to the international development, the development of the area of mechanics, materials and structures of TUD is very good. The main trends in pertinent research were recognised very early. As an example, the long-term programme development of the research programme in the sub-area of concrete structures may be mentioned. Beginning with constitutive relations for concrete some twenty-five years ago, this development has included research areas such as new types of concrete, young concrete, the design of concrete structures for durability, fracture mechanics and information technology. This is one of several examples of scientific leadership at research groups of TUD, together with a number of research groups at foreign universities, in the considered field.

The contribution of the area of mechanics, materials and structures at TUD to the Dutch society is considered to be great. The geo-morphological conditions of the Netherlands and the density of the population require skilful civil engineers with a very good academic training in many fields of civil engineering which are strongly interconnected. The academic education in the area of mechanics, materials and structures recognises the high degree of interaction with other areas of civil engineering. This is reflected, for example, by the research programme Wind Engineering and Offshore Technology. In view of its relevance to the Dutch society this research programme should be strengthened.

Inter- and multidisciplinary work requires a very good knowledge in the primary field of expertise as well as curiosity and ability to enhance the degree of knowledge in other fields. In the area of mechanics, materials and structures of TUD, great efforts are made to help the students developing the skills to meet these requirements.

The group of TUD has close contacts with TNO Building and Construction Research. Staff members have positions at both organisations. The Committee supports the decision of TNO to move the facilities of TNO Building and Construction Research to the campus of TUD.

2.2.5 Water Management

The high level of expertise in water management research, education and practice that resides in Delft is well known and highly respected throughout the world. It is hard to identify a comparable group of universities, research institutes and consulting firms at any one location elsewhere. The water management programmes at TUD are a major contributor to Delft's international reputation for excellence. Water management research that is taking place at TUD in collaboration with other disciplines in the University, and with TNO, IHE and Delft Hydraulics is of top quality.

The interdisciplinary water management programmes at UT are increasingly contributing to the overall quality of the research coming from the Netherlands. Though the overall level of research being carried out at the two universities is believed to be very good, it is not yet at a world-class level. Nevertheless it could and should be if more attention is given to a focussed, highly collaborative research effort involving more PhD students and a higher commitment of faculty time to research.

The importance of this subject to the Dutch society, and indeed to societies in much of the world, is continuously increasing, being driven by growing populations, growing quantities and types of pollutants discharged into water bodies and increasing variability and uncertainty of water supplies.

2.2.6 Geodesy

The Department of Geodesy of the Delft University of Technology is the only full-scale academic research and teaching institution in The Netherlands. Based on its great heritage the Department has developed a research profile which covers most of the range of activities within geodesy, photogrammetry, remote sensing and geographic information.

No one university on this globe can seriously attempt to cover the entire spectrum of a specific field of research and development at an international top level. This, of course, is also true for the Department of Geodesy. Part of the research of the Department, e.g. INSAR, is carried out in the framework of a large interdisciplinary research programme executed by the Delft Institute for Earth-Oriented Space Research (DEOS).

The Department has developed very significant strength in a number of important fields: the most prominent area at the Department is certainly GPS both in regard to theory and application, by taking full advantage of some of the most sophisticated mathematical, statistical and numerical techniques. Another important area of scientific activities with a remarkable profile is satellite-based gravity field determination and satellite radar altimetry. In these two areas the Department has its very strength.

Some of the weaknesses of the Department are related to the implementation of Internet and multi-media technologies in general and its use in GIS applications in particular. Also numerical geodesy is somewhat underrepresented.

Despite of these weaknesses, the Department of Geodesy at the Delft University of Technology ranks among the leading university institutions in geodesy world-wide. Its very high scientific standing is, among others, also expressed by its leadership in several international bodies, by numerous international prizes and by a huge number of citations of the work done at the Department.

3 Evaluation of Research in Civil Engineering and Geodesy per Faculty per programme

3.1 Delft University of Technology, Faculty of Civil Engineering and Geo-sciences

The TUD Faculty of Civil Engineering and Geosciences consists of the Department of Civil Engineering, the Department of Geodesy, and the Department of Applied Earth Sciences. Only the research of the Department of Civil Engineering and the Department of Geodesy is subject to the present assessment.

3.1.1 Department of Civil Engineering

The Department of Civil Engineering carries out research that is related to the engineering practice of the conceptual, functional and detailed design, implementation and construction of civil engineering structures (such as, flood retention or coastal protection schemes, polders, infrastructure and (office) buildings and industrial complexes) and/or the design of the operational tools and facilities ensuring the functional management and use of these structures (such as, water supply, water collection and water sewerage, waste, ground and surface water and traffic control schemes).

The Department carries out both fundamental and application-oriented scientific research. The research (fundamental and applied) is partly multidisciplinary and partly mono-disciplinary in character with a strong societal significance. The research portfolio of the Department consists of seventeen research programmes:

- Building Engineering
- Civil Engineering Informatics
- Design and Construction Management
- Fluid Mechanics
- Geotechnical Engineering
- Hydraulic Engineering
- Infrastructure Planning
- Road and Railway Engineering
- Transportation Planning and Traffic Engineering
- Concrete Structures
- Material Science
- Steel and Timber Structures
- Structural Mechanics
- Wind Energy and Offshore Technology
- Hydrology and Ecology
- Land and Water Management
- Sanitary Engineering

Scientific co-operation takes place with relevant research groups of other faculties, universities (national and international), large technological institutes (GTIs) and the civil engineering industry. This co-operation is partly set-up through national interdisciplinary research programmes such as the Delft Cluster, interfaculty research institutes and networks, Research Schools and the Delft Interdisciplinary Research Centres.

The Delft Cluster is a virtual research network which was formally established in 1999 between the partners: GeoDelft, International Institute for Infrastructural, Hydraulic and Environmental Engineering (IHE), TNO, TUD and Delft Hydraulics. The Faculty of Civil Engineering and Geosciences officially represents the University. The main focus is to perform fundamental, strategic research that will be needed in the long-term for the development of sustainable infrastructure in densely populated delta areas. The ambition of the Delft Cluster is to evolve into a world knowledge centre that will develop and disseminate expertise in the fields of civil and environmental engineering. The Department of Civil Engineering participates in all seven research themes of the network (soil and structure, risks due to flooding, coastal and river engineering, urban infrastructure, subsurface management, integrated water resources management, knowledge management).

The Department participates in four interfaculty research institutes or networks: DUWIND - Institute for wind energy, GOR - Research network for underground space technology, Koiter Institute - Institute for engineering mechanics, and WOT - Research network for offshore technology.

The Research Schools that are organised on a national level mainly provide the framework in which PhD students acquire their education and carry out their research. Each School has chosen its priority research themes in which a number of PhD students co-operate. The Department of Civil Engineering participates in J.M. Burgers Centre - Research School for fluid mechanics, and the Research School Engineering Mechanics. Furthermore it co-ordinates the Research School for Building Structures, the Research School for Hydraulic Engineering, and Research School TRAIL (TRANsport, Infrastructure and Logistics).

TUD is funding the Delft Interdisciplinary Research Centres (DIOCs) to chosen priority research themes to stimulate the integration of research activities. The Department of Civil Engineering is responsible for the DIOCs concerned with Seamless Multimodal Mobility (SMM), The Ecological City, and Water. The Department participates in the DIOCs Behaviour of the Shallow Subsurface, Freight Transportation Automation and Multimodality (FTAM), Reliability of Structures, and Renewable Energy.

In addition to computer facilities for desk and mathematical/numerical research, the Department has research facilities set-up in ten laboratories.

University	TUD		<i>TUD 01</i>
Programme	Building Engineering		
Programme director	Prof. dipl.-ing. J.N.J.A. Vambersky		
Fte 1999	6.6		
Assessment	Quality	3	
	Productivity	3	
	Relevance	3	
	Viability	3	

Building Engineering is a special group dealing with the technical design of buildings whereas architectural design is covered by the Faculty of Architecture. Research in the areas of structural mechanics and structural materials is performed by other groups in the Department. Hence, the research work in Building Engineering is design-oriented. For that reason, the programme was completely reorganised in 1998.

There are now three subgroups working in three different sub-domains: Structural design of buildings, Building physics and building services, and Finishing and materials.

This is a good starting point for integrated research in building engineering, as the aim is to support professional design and engineering practice. The studies on sloping buildings are a good example. However, most of the research work carried out in the past period was based on the old programme which appears to have been too broad and without coherence. The list of academic publications reflects this situation. Some of these publications are of good quality and some fit well in the new programme. This applies, for example, to the fundamental studies on structural morphology and wind-induced dynamic behaviour of tall buildings. Still, the research on building physics is not strong. Since a new professor was appointed in 1999, it is expected that the quality and productivity of research in this sub-domain will increase. In order to be able to meet this goal, the number of researchers should be increased. In this context the Committee strongly advises to strengthen the co-operation with the group on Building physics and Installations in the Faculty of Architecture.

It deserves mentioning that several members of the group retired or otherwise left the group. In the opinion of the Committee the group should increase co-operation with other research groups in the Netherlands and abroad to improve its position in all sub-domains of building engineering.

University	TUD		<i>TUD 02</i>
Programme	Civil Engineering Informatics		
Programme director	Prof. dr. ir. P. van der Veer		
Fte 1999	7.5		
Assessment	Quality	4	
	Productivity	3	
	Relevance	3	
	Viability	3	

The group combines work on hydro-informatics with building and construction IT with the aim of integrating the disciplines of civil engineering, informatics and mathematics.

The work in both areas is energetic, is incorporated effectively into educational courses, and links well with EU initiatives. The quality of much of its work appears good but the amount of published output in relation to its size is average. The Committee was concerned about the way in which the subgroups interact within this programme, as well as across other programmes in the Department and in the University. The vision of the group of a core informatics and mathematical modelling capability that would cut across many of the other areas has been only partially successful, and similarly appears to be only partially viable.

The mission and vision makes an attempt at some coherence, but the actual output fails to reflect it.

The viability of the group depends on a clear strategy for both upstream and downstream interactions. Upstream this group draws on more fundamental developments in computing, mathematical modelling and information systems. Downstream it depends on interactions and collaboration with application areas such as building construction, project management and water resources. Such strategy may be missing, and the rather ad hoc approach followed to date has been only partially successful.

The individual contributions and researchers in this area have been of generally good quality, and of sufficient quantity. These have made relevant contributions to the respective fields of application. However, the whole at this stage does not yet exceed the sum of the parts.

University	TUD		<i>TUD 03</i>
Programme	Design and Construction Management		
Programme director	Prof. dr. ir. Smook		
Fte 1999	2.0		
Assessment	Quality	3	
	Productivity	2	
	Relevance	3	
	Viability	3	

The group has made a valuable contribution through the exploration of a range of issues of importance to the development of the construction industry in the fields of building project management in the context of design, and in planning. The latter has been presented within a novel perception of construction management. The publications demonstrate activity across the research spectrum, covering work concerned with basic methodological development, work of an applied nature and that with a more scholarly orientation. Whilst this work is of reasonable quality, the overall level of output is disappointing, especially the absence of publications in scientific journals. This may be due to the limited involvement of staff with research due to high teaching loads. A contributing factor may be the position of building process research within what the group perceives as a culture dominated by a traditional civil engineering value system reinforced by a university wide policy on the credit rating of publications.

The staffing situation eased in late 2000 creating the prospect of an increase in the amount of research especially in areas relating to design and production methods, for example, lean construction. This will add to the research capacity of the group, which currently is based on the activities of a few staff. Even so the group will remain small and its development constrained by the availability of good research staff, and by a weak dissemination strategy. It would be possible to address the weakness identified if contacts were used to bring in guest researchers from well known international groups.

The group can build on good relationships with industry and other stakeholders in the construction process. It can collaborate further with other groups inside the faculty, such as civil engineering informatics (which is developing key tools for addressing the issues of concern to the group), building engineering, and infra - structure planning, as well as with groups in the Faculty of Architecture and in UT.

The recent AWT Foresight report has placed considerable emphasis on the development of research in the field of the building process and, more generally, in construction management. The group has demonstrated many of the attributes necessary to undertake work of relevance in this field. Nevertheless, progress will be constrained until issues relating to the assessment of its achievements are resolved. In particular, the viability of the group will require greater emphasis on the role and potential of information and communication technologies in the construction process. This necessitates stronger interaction with other groups as well as possible changes in the composition of the skills within the group.

University	TUD		<i>TUD 04</i>
Programme	Fluid Mechanics		
Programme director	Prof. dr. ir. J.A. Battjes		
Fte 1999	12.1		
Assessment	Quality	5	
	Productivity	5	
	Relevance	5	
	Viability	5	

Progress in three fundamental sectors of Fluid Mechanics – 3-D turbulent flows with a free surface, water wave mechanics and the transport of cohesive sediments – has been excellent. These three areas are generic but have also been pursued in an awareness of their relevance to practical problems in the Netherlands and internationally. The quality and originality in this research is, without doubt, leading at international level and maintains the outstanding reputation of the group. The good balance between different modes of pertinent research – analytical, numerical and experimental – deserves mention.

Research productivity is commendably high with fifteen PhD theses in five years, many journal articles published in top quality, internationally recognised journals and two hundred or so additional publications, many having been presented at the leading international conferences in the field. The group collaborates closely with Hydraulic Engineering within the Faculty, to considerable mutual benefit. It also has carefully selected links to groups of similar status internationally.

The academic staff structure is well-balanced, providing a firm basis for continuity as retirements take place. Future research plans are clear, logical and highly relevant. The future potential of the group is very high and no difficulties are anticipated in appointing very able, young, full-time staff as vacancies arise.

It is also noted that the academic staff are able to input relatively high percentages of their time to research, largely a result of reasonable teaching demands. There would be cause for concern if the latter increased with a resulting diminution in the former.

University	TUD	
Programme	Geotechnical Engineering	
Programme director	Prof. dr. ir. A Verruijt	
Fte 1999	9.4	
Assessment	Quality	4
	Productivity	4
	Relevance	4
	Viability	4

TUD 05

The group has pursued research in seven key areas of Geotechnical Engineering with a good balance of analytical, numerical and experimental (largely, but not only, centrifuge) work. This portfolio is based on clear perceptions of generic research needs linked to real, practical problems in the Netherlands and internationally. Over the review period seven PhD candidates have been successful, somewhat fewer in recent years. Surprisingly, considering the quality of the research, relatively few journal papers were published in the review period. A notable “product” has been the group’s core contributions to evolution in the internationally respected and very widely used software package “Plaxis”. The transfer of this practical resource to a private company created in 1993 and run by former TUD students has proved, over the last five years, to have been timely and very successful.

The relevance of the research portfolio of the group is clear and expertise thus generated has been particularly important in relation to specific, sometimes potentially very dangerous, events in the Netherlands. The complementary interests of the group and GeoDelft have continued to develop, to mutual advantage.

The ‘forward look’ in this group properly includes the important areas of underground construction, environmental control, soil subsidence and construction on very soft soils. This is a valid range of topics but there is a need to develop a research plan with somewhat more focussed objectives within these several areas. Additionally, these aspirations need to be linked clearly to the availability of resources to pursue a broadened or extended research programme. In this respect funding appears to present no severe difficulties but the finding of highly able young staff is a considerable problem. The imminent retirement of Professor Verruijt may also give rise to difficulties in appointing a successor – in which a combination of outstanding research potential and breadth of vision to drive a research programme combining generic and practically relevant work are of paramount importance. An increase in research student numbers and publications in recognised international journals would clearly be of benefit to the group.

University	TUD		<i>TUD 06</i>
Programme	Hydraulic Engineering		
Programme director	Prof. ir. K. d'Angremond		
Fte 1999	9.9		
Assessment	Quality	5	
	Productivity	4	
	Relevance	5	
	Viability	4	

The group has a broad but carefully designed and highly relevant portfolio of research. Progress during the review period has been excellent and of outstanding quality judged by international standards. Particularly commendable are the relevance of this research to practical engineering and the properly managed links which allow transfer to the civil engineering profession whilst maintaining the generic research base. The number of PhD theses and journal publications are relatively low considering the size, abilities and reputation of the group. Conference papers, sizeable in number, have been presented generally at the top-level conferences world-wide.

Of some concern is the clearly rather limited amounts of time that many of the academic staff are able to devote to their research. This arises from the very large numbers of students who are attracted to the subject area, resulting in excessive demands on staff time, especially in Masters' dissertation supervision. This load, whilst appearing to be accepted by the academic staff, clearly limits their research input, and output potential. There may well be a case for applying limits on student demand, however unfortunate this might be, in order to adjust the balance between academic staff time spent on education and research.

Future plans are well-stated, based on generic themes of morpho-dynamics and probabilistic methods. In this evolution the highly beneficial and successful collaboration between Fluid Mechanics and Hydraulic Engineering is fully expected to continue, with significant mutual benefits. Both groups make excellent use of top-quality laboratory facilities. Such a laboratory is, without doubt, essential to the pursuit of research in these areas because there remains a lack of understanding of key physical phenomena. It is therefore essential that adequate infrastructure support and continual capital investment in modern instrumentation is maintained.

The prompt appointment of able researchers and teachers to vacancies which arise in the group is also important, as is the replacement of the head of the group on Professor d'Angremonds' retirement. Such a replacement requires a key combination of inherent research ability and breadth of vision to provide appropriate leadership.

University	TUD		<i>TUD 07</i>
Programme	Infrastructure Planning		
Programme director	Prof. ir. F.M. Sanders		
Fte 1999	4.0		
Assessment	Quality	2	
	Productivity	2	
	Relevance	2	
	Viability	2	

The research included in this programme's mission has a very broad scope, loosely organised under the following three themes: strategic planning of infrastructure systems (including land use, transport and environment), physical planning of such systems, and impact assessment of infrastructure-related policies and measures affecting urban areas and regions. These problems are of evident societal importance, as they address the built environment in which people live and work.

The focus of the activities actually performed by the group has been primarily directed at local and national issues. This includes both the problems themselves, which have been very highly context-specific, and the dissemination of the results, which has been limited to the clients themselves, or local and national bodies. Although these results are useful for educational purposes, it appears that the group may be ignoring the opportunity to develop and build on more fundamental scientific principles and conceptual theoretical paradigms, as well as to extract insights and findings with more general applicability from the context-oriented activities that form the bulk of the group's research and professional involvement. As a result the output appears to be lagging in quantity as well as in quality. Very few doctoral dissertations are successfully completed within this group, and very little attention is accorded to the production and publication of refereed journal articles, or papers for presentations at international conferences and other venues. As a result, the group has very limited international profile and exposure.

There does not appear to be a viable vision at the present time to enhance the international competitiveness and scientific quality and relevance of the group. Consideration should be given to the relationship between this group and other groups involved with planning issues. Furthermore the Committee strongly advises to bring in guest researchers from well known international groups to improve the international orientation of the research programme.

University	TUD		<i>TUD 08</i>
Programme	Road and Railway Engineering		
Programme director	Prof. dr. ir. A.A.A. Molenaar		
Fte 1999	10.0		
Assessment	Quality	4	
	Productivity	4	
	Relevance	4	
	Viability	4	

The research programme is divided into sub-programmes concerning road engineering and railway engineering, respectively. The goal of performing hybrid research involving society-driven as well as fundamental research is typical for most of engineering research. The strategy to strengthen the link between the two sub-programmes by means of projects of joint interest is reasonable. At present, there are, however, only three such projects. Two of them are mechanically oriented.

The scientific results both from road engineering and railway engineering reflect the strong mechanical orientation of the respective research programmes. This applies, for example, to the determination of the mechanical characteristics of base materials and sands in relation to physical characteristics, the permanent deformation in concrete block pavements and asphalt concrete response, as far as road engineering is concerned. It also applies, for example, to the investigation of the fatigue behaviour of granular materials and the integrated testing and evaluation system to determine railway track dynamic properties. All of these projects are of great relevance, not only to the Netherlands.

As an important society-driven research work the development of the software programme PASSenger COMfort may be mentioned. The efforts of the group to develop pertinent software is acknowledged. The group is encouraged to continue with these efforts. Usually it should be possible to report on the scientific basis of a relevant computer programme in a suitable publication medium.

The overall quality of the scientific work is good. It is certainly work on an international level. The scientific productivity is good. The same holds true for the relevance and the long-term viability of the research activities. The research group is encouraged to reinforce the co-operation with the research groups on Structural Mechanics and Concrete Structures.

The Committee visited the large scale experimental facility for the testing of pavements and structures, which is a valuable complement to small scale tests and theoretical work.

University	TUD	<i>TUD 09</i>
Programme	Transportation Planning and Traffic Engineering	
Programme director	Prof. dr. ir. P.H.L. Bovy	
Fte 1999	14.1	
Assessment	Quality	5
	Productivity	5
	Relevance	5
	Viability	5

This programme is conducting fundamental research in traffic and transportation processes at the highest international level, in problem areas that have direct relevance to the national context. The research addressed in this programme is broad in scope, yet deep in its approach and contribution. The programme has developed clear poles of excellence, and maintained a high degree of coherence through several cross-cutting characteristics shared by the various problems and approaches developed. This group has positioned itself over the past five years as a dynamic centre of innovative research in the most challenging areas of transportation and traffic systems planning and engineering: dynamic analysis, real-time control, transport informatics, and characterisation of complex multi-class flow processes. The group enjoys wide international recognition for its efforts, and is among the world's leading institutes in its area of expertise, with extensive participation in the principal international forums in this domain.

The group is pursuing a sound strategy for publication and dissemination of its results, with high priority given to submission to international scientific archival journals, and participation in international conferences, while at the same time translating the results of the research into software and reports for use by the practising professional community. The production of doctorates, scientific and professional publications is excellent, and has shown considerable increasing trend which appears to be continuing.

The group is engaged in several international collaborative efforts, at the European level as well as with the US and Asia. The group attracts students from several international sources, as well as from a variety of disciplines.

The work and scientific production of the group possesses a high degree of relevance, scientifically and professionally. Traffic and mobility problems are among the top concerns of our society, and development and application of new technologies is an important mission of scientific, professional, economic and social relevance. The work of the group is making an important impact, nationally and internationally.

The group enjoys solid, dynamic leadership, with excellent strategic vision and a high degree of commitment to the highest standards of scholarship and professionalism. The viability of the group is judged to be excellent.

This group can be viewed as a highly successful example of interdisciplinary research and education, in content (integrating several disciplinary streams, such as applied mathematics, operations research, physics, behavioural science and engineering), as well as in collaborative programme participation (through DIOCs and various other intra- and inter-university associations).

University	TUD		<i>TUD 10</i>
Programme	Concrete Structures		
Programme director	Prof. dr. ir. J.C. Walraven		
Fte 1999	13.3		
Assessment	Quality	4	
	Productivity	4	
	Relevance	4	
	Viability	5	

The major goals of the research programme are to improve safety, serviceability and durability of concrete structures. The programme development over the last 25 years, beginning with constitutive relations of materials around 1975 and leading to research on new types of concrete, young concrete, and durability of concrete structures, indicates that major trends were recognised in good time. The statement that “good designs are based on a sound knowledge of both material and structural behaviour” reflects the research strategy that is considered to be reasonable for an applied area of civil engineering.

The development and progress of the research group is assessed by the scientific output in the review period in areas such as design of concrete, new types of concrete, young concrete, the design of concrete structures for durability, fracture mechanics and information technology. The quality of the output is high. Its relevance is great. The successful application of young concrete is acknowledged. This research has many practical implications.

The position and reputation of the research group in the international research community is good. The overall quality of the scientific work is of high international level. It is, therefore, rated as good. The scientific productivity in terms of completed doctoral dissertations is good. As regards journal articles, a continuous decline from 10 in 1995 over 4 in 1997 to 2 in 1999 is observed. This may be explained by the fact that a very productive programme member left in 1997. (The number of doctoral dissertations completed in the year 2000 and 2001 are 2 and 4, respectively. Although they do not refer to the evaluation period, they indicate that, more recently, the productivity has increased.) Relevance and viability of the research programme are rated as good and excellent, respectively.

This group, as well as the group on Steel and Timber Structures, make use of excellent laboratory facilities. It is of great importance that capital investment in new equipment is maintained, because also in these fields theoretical and experimental research go together. The experimental equipment for the testing of shield-driven tunnels is unique. The research group is encouraged to seek international co-operation with high-calibre groups working in the area of computational mechanics of tunnelling.

University	TUD	<i>TUD 11</i>
Programme	Materials Science	
Programme director	Prof. dr. ir. Ch.F. Hendriks	
Fte 1999	10.6	
Assessment	Quality	4
	Productivity	4
	Relevance	4
	Viability	4

The main goals of the research programme are the investigation of the properties and the behaviour of building materials, considering chemical, physical, and mechanical influence factors, and studies on durability, sustainability, and environment. In view of the relatively small size of the research group these goals are certainly not too narrow. Research results from projects dealing with recycled aggregates in high tolerant concrete or with the recycling and re-use of building components are considered as timely contributions to materials science in the context of civil engineering. The development of an environmental input assessment method for urban areas is a relevant research topic although it is not quite clear how closely this topic is linked to what is commonly understood by materials science. Nevertheless, a timely expansion of the scope of this discipline is viewed as positive.

Topics such as durability of construction materials and sustainability are of great public and technological relevance. The title of one of the papers by the research group, “Concrete: durable, but also sustainable?” indicates the awareness of the authors as regards significant differences between the terms durability and sustainability of building materials.

The development and progress of the research group are measured by the scientific output in the initially mentioned areas during the review period. Both the quality and the relevance of the output are on a good international level. The international position and reputation of the research group is good. The scientific productivity in terms of completed doctoral dissertations is, however, below standard. The continuous increase of the research input of the academic staff in the period 1995 – 1999 is not reflected by an increase of the number of doctoral dissertations. The programme director indicated that such an increase will occur in the near future. The situation is a bit better with regards to journal articles and significantly better with other publications. This is reflected, for example, by a number of books, written by the programme director, which have appeared in the review period on topics such as “Durable and sustainable construction materials”, “Sustainable constructions”, “The building cycle” and “Building materials (two volumes)”.

University	TUD		<i>TUD 12</i>
Programme	Steel and Timber Structures		
Programme director	Prof. dr. ir. J. Wardenier		
Fte 1999	11.6		
Assessment	Quality	4	
	Productivity	4	
	Relevance	4	
	Viability	4	

The development of models, techniques and design tools to describe the static and fatigue behaviour of structural components or structures of steel, timber, composite construction, and fibre reinforced plastics is a rather traditional albeit necessary goal for a research group engaged in a programme on Steel and Timber Structures. The development of innovative products and structural concepts is an important mission, considered to be indispensable for a modern research group in the area of structures. Obviously, this task cannot be achieved without close interaction with the pertinent industry.

The overview of academic results indicates that a number of relevant topics were dealt with, such as hollow section joints, beam to column connections and column bases, and orthotropic steel decks in the area of steel structures, multiple fastener joints and long-term behaviour of timber connections in the area of timber structures, and longitudinal shear connections of composite steel-concrete slabs as well as such composite slabs under fire conditions in the area of composite structures. Experimental work in the form of full-scale tests on rotor blades for wind generators, made of fibre reinforced plastics, also deserves mention. These tests are impressive. The question about the relevance of research on orthotropic steel decks was answered convincingly.

The development and progress of the research group is measured by the scientific output in the review period. Its quality and relevance are high. It is, therefore, rated as good. The scientific work of the research group appears to have a strong impact on the improvement of national and international design recommendations. The position and reputation of the research group in the international research community is good. This group plays an active role in pertinent international committees and working groups. The scientific productivity in terms of completed doctoral dissertations, journal articles and professional publications is good. The strength of the group is seen as an advantage, stimulating the competition between structures made of different traditional and non-traditional materials.

University	TUD	
Programme	Structural Mechanics	
Programme director	Prof. dr. ir. J. Blaauwendraad*	
Fte 1999	24.2	
Assessment	Quality	5
	Productivity	5
	Relevance	5
	Viability	5

TUD 13

The research programme consists of the following three sub-programmes: mechanics of structural systems, computational mechanics, and mechanics of materials. This is a timely and logical subdivision. What is needed for genuine progress in the area of structural mechanics is an intelligent synthesis of these three sub-programmes. Successful efforts of the members of the research team in this direction are acknowledged.

Both the originality of the scientific approach and the significance of the contributions to the field deserve to be rated as excellent.

The sub-programme computational mechanics belongs to the best of its kind in the world. It is a very good blend of fundamental work, the development of algorithms for non-linear mechanics with an emphasis on material modelling of concrete, and the implementation of these algorithms into computer codes, such as DIANA. What perhaps should be strengthened is the structural component of this research. World-wide there is an overweight of research work in the area of computational mechanics of materials. Relatively little of this work – among it research results from the Delft group – is applied to non-linear structural analysis of challenging civil engineering structures made of different materials such as, for example, concrete.

As regards the scientific work of the two other subgroups, it is acknowledged that the research team on mechanics of structural systems is considering the random nature of dynamic loads in the context of research on high-speed railways on soft soils. Also the work on masonry structures is worth mentioning. The co-operation of this subgroup with the group of Road and Railway Engineering on modelling of pavements is acknowledged. Referring to the subgroup on mechanics of materials, both the high quality and the great relevance of research on the mechanics of cement-based materials are appreciated. Efforts should be made that the curiosity-driven component of the research on fracture mechanics of concrete and rock is accompanied by a sufficiently strong practice-oriented component of pertinent research, characterised, for example, by suitable translations of relevant research results into specifications for practising engineers. The high competence and the great enthusiasm of the person in charge of the newly established micro-mechanical laboratory are a good basis for top-calibre research in the area of fracture mechanics of concrete. The Department of

* Professor De Borst was co-programme director (1995 and 1996) and programme director (1997 and 1998) of the Structural Mechanics Programme.

Civil Engineering should try to maintain its leading position in this research area. At the same time the Department should insist that the knowledge gained in this fundamental research is transferred to more practical sub-areas of structural engineering.

Quality, productivity, relevance, and long-term viability of the research programme are all outstandingly high. It is, therefore, justified to rate each one of them as excellent. Based on the citation index one of the members of the research group, who has left the Department of Civil Engineering, has an extraordinarily strong position. Three members, one of whom has been heading the sub-programme Computational Mechanics for the last two years, have very strong positions. Their scientific works have contributed significantly to the high reputation of this Department.

University	TUD		<i>TUD 14</i>
Programme	Wind Energy and Offshore Technology		
Programme director	Prof. dr. ir. G.A.M. van Kuik		
Fte 1999	10.2		
Assessment	Quality	3	
	Productivity	3	
	Relevance	4	
	Viability	4	

The programme consists of two sub-programmes as is reflected by its title. The goals of the combined programme are to develop theories, models and computer programmes for an offshore wind energy converter under operational conditions, and for the design and optimisation of such a converter and its major components. In order to achieve these goals, research work is done in areas such as integrated design methodology, modelling of wind, rotor aerodynamics, probabilistic design methods, and wind energy in the built environment. These are essential components of research which by its nature is inter- and multidisciplinary.

The societal and technological relevance of the development of offshore wind energy and of the solution of the underlying scientific problems is undisputed. However, the visibility of research activities in the area of offshore technology is relatively small. The research record of the group is rather standard. It is based to a larger extent on professional publications than on scientific publications and doctoral dissertations. This is reflected by the citation indices which are not very convincing, and by the small number of doctoral dissertations in the evaluation period. Unfortunately, so far there exists no journal on offshore technology. Such a journal could serve as a natural publication medium. In view of the importance of the research programme and the relatively great number of components of this programme, efforts should be made to increase the number of doctoral students. Normally, the scientific productivity is correlated to this number. It is recognised that the research results are directly implemented into the educational programme.

In the opinion of the Committee the programme on Wind Energy and Offshore Technology should be strengthened.

University	TUD		<i>TUD 15</i>
Programme	Hydrology and Ecology		
Programme director	Prof. dr. ir. C. van den Akker		
Fte 1999	12.3		
Assessment	Quality	4	
	Productivity	3	
	Relevance	3	
	Viability	4	

This programme focuses on the interactions among surface and groundwater hydrology, geomorphology, and water quality. It examines the factors that determine the temporal and spatial distribution of water quantity and quality, and, the Committee would assume, their ecological impacts. The research programme has been divided into two components: one that concentrates on groundwater quantity-quality modelling and another on surface water hydrology and ecology. The stated mission is to improve understanding of processes and to provide modelling support to managers and other researchers involved with water management issues. The group encourages international collaboration and co-operation including student residence at universities away from TUD.

The research productivity of the faculty in the programme has been uneven. The research programme is becoming increasingly productive and influential and the publication record shows a trend toward greater numbers and quality in the past five years. However, efforts toward linking hydrology to ecology seem to be limited to including algae in water quality models. Given the increasing interest in eco-hydrology involving the linking of hydrology to aquatic and terrestrial ecosystems, there seems to be an excellent opportunity for the group to extend work in this area. It is surprising that research activity has not developed further in this area.

The fte research input is 12 (1999) but this is largely made up (75%) of junior staff and research fellows. Such a structure is fine, indeed essential, provided senior academic guidance is adequate. In this context the Committee notes that the programme director is only 0.1 fte involved in research.

The group has made steady progress in research but had not made a strong international impact as would be expected on this topic. The limited PhD candidates (two in last three years) is disappointing but the Committee recognises that external factors may apply. The future of a programme in hydrology and ecology should be bright. This subject is experiencing a growth in interest and international funding. There are many opportunities for increased funding and collaboration. The Committee thinks it important to strengthen the collaboration with other water management programmes in Civil Engineering, including the hydro-informatics sub-programmes and the research activities taking place in the Policy Analysis and Systems Engineering Faculty. The group produces a number of software products demonstrating good, and essential, links with professional practice.

University	TUD		<i>TUD 16</i>
Programme	Land and Water Management		
Programme director	Prof. ir. R. Brouwer		
Fte 1999	6.5		
Assessment	Quality	4	
	Productivity	4	
	Relevance	4	
	Viability	4	

Research in this programme focuses on the management of land and water resources to meet society's objectives. Research activities are divided into three main components: design of rural and urban water management systems, operational control and maintenance of these systems, and integrated water resources planning and management. The latter is very interdisciplinary and requires collaboration with other academic departments and expertise. These three research components contain substantial overlapping interests, and hence there is interaction among those pursuing research in each of the components. Optimisation of water usage is critical nationally and internationally; future plans for this sector demand the filling of the vacant chair and the development of a more detailed programme, including perhaps more input or consideration of land use.

The programme has a very good reputation among those working in water resources planning and management. Many of the programme faculty are very well known internationally. The programme's publication record shows increasing productivity over time. Most of the publications are conference proceedings. The Committee would like to see a greater proportion of journal papers among the numerous publications. The number of dissertations also seems relatively low, no doubt reflecting the limited number of PhD students. The software products of the group are substantial and are being successfully used in practice.

The research results have contributed to our general scientific knowledge as well to the capabilities of those responsible for water resources planning and management in The Netherlands. Most of the research is focused on solving practical problems facing current water planners and managers. Some of the faculty have close contacts with the practice of water planning and management, locally and internationally.

This subject is becoming increasingly important, especially in developing countries but also in the developed world where water quality and allocations of scarce resources are of importance. There are many opportunities for future funding and collaboration. The Committee thinks it important to maintain and strengthen the collaboration with other water management programmes in Civil Engineering, including the hydro-informatics sub-programmes and the research activities taking place in the Policy Analysis and Systems Engineering Faculty.

This programme has the potential and should strive to become world-class. The establishment of a combined, co-ordinated and well focused research programme involving all the water management programmes in Civil Engineering, perhaps together with the hydro-informatics group and those in the Policy Analysis and Systems Engineering Faculty, interacting with other disciplines as appropriate, at least as viewed by the outside world, would be a substantial critical mass of talent few if any other academic institutions could match. (Note: This is not a suggestion for any administrative changes.)

University	TUD	
Programme	Sanitary Engineering	
Programme director	Prof. ir. J.C. van Dijk	
Fte 1999	7.4	
Assessment	Quality	4
	Productivity	5
	Relevance	4
	Viability	4

TUD 17

This research programme focuses on water and wastewater treatment systems. The research has been carried out in close collaboration with companies producing and using such technology and includes laboratory to full-scale facilities for testing new technology. Membrane filtration has been of particular interest. Results include publications and software programmes for using models to analyse water and wastewater treatment processes and systems. The research programme includes work on integrated water and wastewater treatment systems including wastewater reuse.

The programme's publication record shows increasing productivity since 1995. The number of dissertations is very reasonable for the number of faculty members. The Committee notes that many publications are journal articles and not primarily conference proceedings, published in journals of excellent international quality. The research results contribute to our general scientific knowledge as well as to practical solutions to treatment technology challenges and problems.

The future potential for this programme is very good. While this subject is an old one it is no less needed now than in the past. People are demanding higher quality standards and there are increasing amounts and different types of pollutants to treat. The Committee encourages continued collaboration with hydraulic engineering, and with the water management programmes in both the Civil Engineering Faculty and the Policy Analysis and Systems Engineering Faculty.

We have learned there is no required undergraduate course that introduces sanitary engineering to undergraduate students, and this might result in a decrease in graduate student input simply because some students will not even know the discipline exists.

3.1.2 Department of Geodesy

The Department of Geodesy is the only scientific institute in the Netherlands which is responsible for the entire field of Geodesy including both research and education. The Department's position is therefore unique in the academic and engineering landscape of the Netherlands. The Department has its own educational programme which is closely linked to its research and it provides one of the three independent curricula catered for within the Faculty of Civil Engineering and Geosciences, the two others being those of the civil engineering and the technical earth sciences programmes.

Since 1996 the Department's research has been organised according to its division into five sections and it is accommodated in the following five key programmes:

- Physical, Geometric and Space Geodesy
- Mathematical Geodesy and Positioning
- Photogrammetry and Remote Sensing
- GIS Technology
- Geo-information and Land Development

The Department is involved in various co-operative research programmes and institutes. It participates in four of the nine Delft Interdisciplinary Research Centres (DIOCs), as well as in the Delft Research Schools TRAIL (Research School for TRANsport, Infrastructure and Logistics), ASCI (Advanced School for Computing and Imaging) and Nethur (Netherlands Graduate School for Housing and Urban Research). The Department leads the scientific programme of the Dutch Active GPS Reference System (AGRS-NL) and heads the Delft Institute for Earth Oriented Space Research (DEOS), which participates in the Vening Meinesz Research School of Geodynamics (VMSG) and in the Netherlands Research Centre for Integrated Solid Earth Science (ISES). The Department is also affiliated to the Research Institute for Policy Sciences and Technology (OTB) and it has formal relations with the International Institute for Aerospace Survey and Earth Sciences (ITC) through the Centre for Cadastral Studies.

The Department has a GPS laboratory and shares a calibration facility for surveying equipment, computer rooms, a library and a museum. The Department also owns a fairly complete arsenal of modern instrumentation and computer hardware. The astrometric VLBI observatory in Westerbork, established to replace the Kootwijk satellite observatory, is configured with permanent GPS equipment for the AGRS-NL and the International GPS Service (IGS), and with stable platforms for hosting absolute gravimeters and mobile SLR equipment.

University	TUD	<i>TUD 18</i>
Programme	Physical, Geometric and Space Geodesy	
Programme director	Prof. Dr.-Ing.habil. R. Klees	
Fte 1999	11.1	
Assessment	Quality	4
	Productivity	3
	Relevance	4
	Viability	4

The key elements of the research profile are in line with the mainstream of the international scientific community of Theoretical and Space Geodesy. Compared to the 1989-1993 programme, research related to boundary value problems was intensified. In particular, integral equation techniques and boundary elements methods have been added to the research programme and were successfully integrated with the ongoing activities. This research is triggered by the new gravity field missions, which make the formulation of more accurate mathematical models for the combination of high-resolution terrestrial data and high-accuracy satellite data necessary. Moreover the programme also covers activities in the area of synthetic aperture radar investigations.

The programme team co-operates with national and international research centres and participates in both national and international research programmes. In particular, the group contributes to the large interdisciplinary research programme Earth-Oriented Space Research executed by the Delft Institute for Earth-Oriented Space Research (DEOS). This research programme covers the closely interrelated subjects “the Earth’s gravity field”, “precise orbit determination”, “geokinematics”, “geophysical signals”, and “instrumentation and operation”.

Being exclusively geodesists, the staff members have a purely homogeneous background. Considering the multidisciplinary character of the research programme, staff with a somewhat wider educational spread would contribute to the performance of the team. However, it is questionable if the depth of research can be achieved or maintained when the spectrum of scientific activities is very wide.*

The programme’s director is strongly engaged in the work of national and international organisations. The relevance of the programme to the advancement of research in the field of space geodesy is being considered as high.

The productivity of the team must be rated average compared to similar international research teams; the number of PhD theses is relatively low. However, the quality of the scientific publications is good. The scientific long-term viability of the team could be quite positive provided that both staff recruitment takes place quickly and that the team focuses on a smaller number of key topics.**

* Meanwhile the Committee was informed that the background of the present staff covers various disciplines, that fit the multidisciplinary character of the research programme.

** Meanwhile the Committee has learned that the vacancies have been filled and four PhD projects which started in 1994 and 1995 have successfully been defended.

University	TUD	<i>TUD 19</i>
Programme	Mathematical Geodesy and Positioning	
Programme director	Prof. dr. ir. P.J.G. Teunissen	
Fte 1999	7.8	
Assessment	Quality	5
	Productivity	5
	Relevance	5
	Viability	5

The team around Professor Teunissen has developed a scientific profile over the past years which is highly recognised by the international scientific community and which ranks among the very best world-wide. It is characterised by a strong focus on GPS in general and on the solution of mathematical, numerical as well as statistical problems in context with the processing of GPS data in particular.

The team has a clear guiding belief, a crystal-clear mission which aims at a top level performance in a limited number of topics within GPS applications. And the goal which had been defined years ago has indeed been achieved. The group has developed very powerful techniques for integer ambiguity search, it has established a permanent GPS network in The Netherlands, it has achieved a scientific outreach which goes far beyond GPS by covering also topics such as VLBI, dINSAR, etc. The software developed by the group is of scientific nature, however, it is very useful for practical applications. It is made available mostly free of charge to university institutions. Software distribution provides a means of disseminating latest state-of-the-art processing procedures rather than making financial profits. The programme team co-operates with several scientific institutions all over the world. The project-oriented research work is being well selected with emphasis on being in line with the defined programme goals and with scientific profit being given a much higher weight than to financial aspects.

The productivity in general and of the programme director in particular is very high. The number of PhD theses is above average with the potential of being increased further, provided that a sufficient number of capable students can be attracted. Currently the group relies on foreign PhD students due to the lack of Dutch candidates. The group is also very successful in attracting students from areas other than geodesy.

The relevance of the scientific work is extraordinary and so is the long-term viability. The entire research programme could well serve as an almost perfect example for a very well functioning scientific university institution both nationally and internationally.

University	TUD		<i>TUD 20</i>
Programme	Photogrammetry and Remote Sensing		
Programme director	Prof. dr. ir. George Vosselman		
Fte 1999	4.9		
Assessment	Quality	3	
	Productivity	3	
	Relevance	3	
	Viability	4	

The group has made research in the following subtopics of photogrammetry: Close range photogrammetry, Semi-automatic mapping, and Laser altimetry. The programme director explained to the Committee his decision to focus on large scale geo-information. The remote sensing research on active data collection is carried out in the programme Physical, Geometric and Space Geodesy (TUD 18). This research, e.g. INSAR, is carried out in the framework of the Delft Institute for Earth-Oriented Space Research (DEOS). The scientific output is given in an international context, which is acknowledged by the Committee. The overall mission is to deliver efficient methods for 3D geo-information production, also a relevant topic especially in large scale applications.

Though the number of academic publications has been relatively low most of the period under review the continued growth of output is acknowledged. The Committee recommends to supervise more PhD students than before to increase forefront photogrammetric research. The group leader is an internationally acknowledged expert and can therefore attract scientific collaborators from all over the world. The Laser altimetry work is very good and should be continued in the near future, integrating multi- and hyper-spectral imagery.

The Committee is optimistic that this group has high potential for forefront work in photogrammetry and remote sensing. The viability of this research programme therefore is considered good, while during the review period the overall quality of the research is rated standard. The Committee encourages the group to widen its focus, to co-operate especially in house with the GIS technology group and to continue and strengthen its efforts co-operating with groups outside TUD.

University	TUD		<i>TUD 21</i>
Programme	GIS Technology		
Programme director	Prof. dr. ir. M.J.M. Bogaerts/Prof. dr. P. van Oosterom		
Fte 1999	4.8		
Assessment	Quality	3	
	Productivity	3	
	Relevance	3	
	Viability	4	

The overall focus of the research programme lies on five sub-programmes: Interoperability and Standardisation, Land Registration, Quality of Geo-information, 3D-GIS and visualisation, and Linking GIS with (dynamic) models. Not yet reported were most recent activities in Internet GIS and mobile GIS applications. The productivity of the group in terms of journal articles and PhD theses is rather low. However, the productivity for international conference proceedings is quite high. Given the nature of research on GIS, most publications are based on software developments.

The group leader has been appointed professor in 2000, therefore this personal change could not yet have made strong impact on the productivity in the period under review. But it seems that the group has realised the challenges of GIS technology in an international context and is highly motivated for the future. This results into a viability assessment of above average. The collaboration with research institutes and industry seems worthwhile and is expected to contribute to the productivity in the near future. Spatio-temporal aspects of spatial data may be more appropriate and detailed than linking GIS with (dynamic) models.

The Committee recommends that the group should be active in all the above mentioned fields. Co-operations should be made, not only with the internal Department groups (geo-information, photogrammetry, mathematical geodesy) but also with other disciplines like computer science, geography, electrical engineering etc. Creating an open minded scientific atmosphere will attract good PhD students not only from Geodesy but also from other disciplines, which is especially important for forefront GIS science.

University	TUD		<i>TUD 22</i>
Programme	Geo-Information and Land Development		
Programme director	Prof. dr. J. de Jong		
Fte 1999	7.1		
Assessment	Quality	3	
	Productivity	3	
	Relevance	3	
	Viability	4	

The main line of the programme is focusing on three topics: Geo-information engineering, Urban land development, and Rural land development.

The work is mainly focused on the national cadastre, for which research especially in the field of rural land development has been carried out. GIS technology is used for large scale spatial data. Most of the publications are written in Dutch and therefore not accessible for an international audience. There is no doubt that some service for the national community is expected and part of the work is linked to the Dutch legal and administrative system, but in the meantime also urban and rural land development are discussed on an international scale. Highly developed Western Countries such as the Netherlands could and should export knowledge in this societal important field to the Eastern Block countries and into the Third world. Also Geo-Information engineering is today discussed in international forums and committees.

During the period under review there was a considerable change of staff. Also the productivity of the group, with one PhD study completed, was modest during this period. The Committee acknowledges the start of various new PhD studies.

The Committee recommends, as did the previous review committee in 1995, that the research results of the group should be made public also for the international scientific community. The group is therefore encouraged, to focus its research to an international context being a potential partner for international funding organisations as well as to attract PhD students from abroad.

As stated in the introduction of this report, the Committee is of the opinion that the quality, productivity and relevance can not be rated above 'standard' when the research output does not make recognised contributions to the international research community. Hence quality, productivity and relevance of this programme are rated standard, while the viability is judged to be good.

3.2 University of Twente, Faculty of Technology and Management, Department of Civil Engineering

The Department of Civil Engineering is embedded in the Faculty of Technology and Management. The Department wants to operate at the interface of Civil Engineering, Business Management and Public Administration. It attempts to acquire qualitative and quantitative knowledge on all phases of the lifecycle of civil engineering systems and objects, that is, initiative, design, production, operation, maintenance, and demolition, all in a societal and environmental context. The research carried out by the Department consists of four programmes:

- Construction Engineering & Management
- Integrated Modelling of Civil Engineering Systems
- Transportation Engineering & Management
- Water Resources Management

The Department of Civil Engineering participates in two Research Schools: the Netherlands School for Advanced Studies in Construction, and the Netherlands School for Advanced Studies in Hydraulic and Geotechnical Engineering. The Department also participates in the Netherlands Centre for Coastal Research (NCK) and the Netherlands Centre for River Studies (NCR), which have both been founded in close co-operation with the latter research school. In 1999 the corporation P3BI was established. P3BI, a co-operation of public as well as private organisations, aims to bridge the gap in research and development between construction industry and science. The Discipline Group of Construction Engineering & Management has scientific and personal links with P3BI.

Priority has been given to investments in computer equipment, networks and facilities, including libraries with application software and home facilities. Because of the interdisciplinary nature of the research a large proportion of experimental tests can be characterised as field research. Therefore, investments in laboratory equipment are rather modest and basic. In case of a need for advanced experimental methods, facilities are leased from research partners (for example, TNO, Delft Hydraulics, TUD).

University	UT		<i>UT 01</i>
Programme	Construction Engineering and Management		
Programme director	Prof. dr. A.G. Dorée		
Fte 1999	3.3		
Assessment	Quality	2	
	Productivity	2	
	Relevance	3	
	Viability	2	

Over the period the group has been required to define its mission and relevance within an interdisciplinary area which brings together elements of engineering, management and the social sciences and to develop appropriate research direction and projects. This process has been constrained by staff shortages, heavy teaching loads, and difficulty attracting research students. This has significantly delayed the development of construction process research. Consequently, achievements in this field have been limited. However work in the field of construction technology has been relatively unaffected by these difficulties and the outputs are sound. It was reported during discussions with the group that the difficulties faced by the construction process activities had continued during 2000. However as a result of two appointments made in late 2000 and the development of P3BI, which is expected to provide additional resources for research, by 2002 the performance of the group should have improved. This improvement will also depend on a plan to reorganise the group, whereby the construction process activities will be separated from the construction technology activities, enabling each activity to have a more clearly identified mission.

The Committee was concerned that although the resources of the group have increased, the existing high workload of staff, especially that of the head of the group, will continue. Teaching loads will not decrease substantially and the management and organisational responsibilities associated with P3BI will be quite demanding. Additionally, the Committee expressed concern about the proposed singular focus on the construction process and a distancing of technology, and to some extent IT. This is an area which requires a good understanding of emerging technological developments and the influence of IT on the organisation of projects, firms and business in general. Whilst the reorganisation is likely to encourage a broad and strategic involvement with the complete process of development and construction, and is to be welcomed, this may be at the expense of a concern for the effective management of projects and production.

The recent AWT Foresight report has identified the building process as being a key area for a higher level of research and education in order to meet the needs of the Dutch construction industry, its clients and other stakeholders. The Committee considered that the group has a very important part to play in meeting these needs of industry and society. Whilst the group is undoubtedly making a major contribution through its education programmes, its research achievements have been modest and consequently the relevance of its research programmes has been somewhat limited.

The modest nature of the research achievements are reflected principally in the construction process work, the output of publications of all types, in a field which lends itself to dissemination in both scientific and professional publications was low in terms of both quantity and quality. The outputs in the area of building technology were stronger.

Although some valuable building science work had been undertaken and the application of theory from the social sciences to issues in construction has been usefully demonstrated, there had not yet been a strong demonstration of the contribution to be made by the interdisciplinary perspective taken by the group. However, more recently, there had been a clear demonstration of its appeal to external sponsors of research by the setting up of P3BI.

This group is at a critical juncture; it is positioned in an area of high demand from students and industry. However it has yet to demonstrate that it can produce or disseminate the kind of fundamental and applied research expected in a University context. It has had a rather difficult start through pursuing an unbalanced and unrealistic sense of priorities, and because of a growing distance from the research process.

University	UT		<i>UT 02</i>
Programme	Integrated Modelling of Civil Engineering Systems		
Programme director	Prof. dr. ir. H.J. de Vriend		
Fte 1999	9.1		
Assessment	Quality	4	
	Productivity	4	
	Relevance	4	
	Viability	3	

The original concept in programme formulation at UT was that this group would form a focus in the development of generic modelling concepts as input to the other three research programmes in the Civil Engineering and Management Department.

The group clearly has developed innovative and original modelling components such as model aggregation and capabilities to include uncertainty and “scaling up”. These have been applied successfully in the field of morpho-dynamic modelling in the marine environment. This topic was seen as the “vehicle” for the building and testing of generic modelling components.

In morpho-dynamic modelling the group has clearly been successful, developing an international reputation in the field. In this, productivity has been very good with commendable publications in top-level journals. There is, therefore, no doubt as to the international status of the group in the aquatic morpho-dynamic modelling field.

Sincere and strenuous efforts have been made to “export” the key modelling concepts into the socio-economic sector, a perfectly valid objective driven by the intellectual vision of the group leader. Unfortunately this aspiration has not been successful, neither within the group nor within the three other research groups in the Department. This conclusion of the research group leader, which is supported by Professor Wind, is shared by the Committee. A revised policy is now being implemented in which the development and application of new modelling concepts will be undertaken within each of the research groups individually. The Committee agrees with this new policy. Clearly, the new research strategy in this respect has been carefully considered and the revision will hopefully lead to valid evolution of novel modelling concepts within each group, subject, of course, to the viability of those groups individually.

Considering only the morphological modelling, its relevance is clear and gives promise of significant advances in such modelling at larger physical and temporal scales. It does, however, seem that a combination of this group with that in Water Resources Management would be beneficial. Reorganisations in the Department structure indicate that such an amalgamation is intended.

The Committee was given to understand that the group leader may reduce his involvement at UT – he is involved in compatible research at TUD. This will have an impact on the research momentum in the aquatic morphological sector in Twente, despite the remaining academic staff having well-established international reputations in this field. It is therefore considered to be most important that the numbers of research staff in this topic should be maintained. It is also highly desirable that the leading academic should be a full-time member of the staff in order to build on and extend the present momentum in a coherent and well-managed way. This would, at least, provide an opportunity for the present commendable links between the group and other organisations within the Netherlands to be increased and extended to international level. There is much to be gained from the latter and there is a clear potential for high-level contributions to the topic in the future.

The Committee has some concerns that structural and managerial changes within the University may well hamper the future programme if they are not implemented as rapidly as is feasible.

University	UT	<i>UT 03</i>
Programme	Transportation Engineering and Management	
Programme director	Prof. dr. ir. M.F.A.M. van Maarseveen	
Fte 1999	4.5	
Assessment	Quality	4
	Productivity	3
	Relevance	4
	Viability	4

This programme conducts research in the general area of transportation engineering and management, with a focus on land transport. The research aims at development of mathematical tools for the planning and evaluation of transportation facilities and systems, and decision support systems to aid in the planning and management of traffic facilities, particularly through the use of real-time information to travellers. The mission of the programme fits well with the strengths of UT in management, information technology, and applied mathematical sciences. The programme is relatively young, and is only now approaching sufficient critical mass. It has produced a good record of quality scientific and professional output, and is making good progress towards greater dissemination of research results through the international scientific community. The group has articulated a clear mission of contributing to the profession through education and scientific research, and is following a sound and heretofore successful strategy to achieve its mission.

The group has access to various funding sources and opportunities, of which it is making good use. There is considerable demand for its educational and research services, and its growth appears constrained by the ability to identify, attract and retain research staff and doctoral students. The programme has introduced several measures to address some of these limitations, and is making good progress in this regard. While its focus has been primarily on education and production of research driven by national needs, its contributions are relevant and significant to the international scientific and professional community.

The programme is engaged in several collaborative inter-disciplinary activities on campus and with other organisations. These enhance the value and quality of the programme and its research opportunities. The subject areas addressed by the group, namely mobility at the urban, regional and national scales, are highly relevant to society and the national economy.

This group appears to be on a good course of growing in output as well as in quality and stature. It is a young dynamic group, with a good esprit de corps and sense of purpose. It will undoubtedly continue to thrive and grow, and contribute to fulfilling its mission.

University	UT		<i>UT 04</i>
Programme	Water Resources Management		
Programme director	Prof. dr. ir. H.G. Wind		
Fte 1999	4.7		
Assessment	Quality	4	
	Productivity	4	
	Relevance	4	
	Viability	4	

This research programme focuses on the integrated management of water resources and the development and implementation of computer-based decision support systems that can assist decision makers responsible for planning and managing these resources. The programme emphasises the multi-disciplinary aspects of water management and thus covers the interactions among socio-economic, ecological and geophysical processes. Results include graduate students, publications, and decision support system software.

The programme's publication and software development record shows good productivity over time. While not a large programme, it seems to us to be a high quality one, especially given the human resources available. Refereed journal papers in quality international journals make up about a third of their total academic publications. The research is motivated by real problems. The programme has a good reputation among those working in the water resources planning and management profession in the Netherlands and abroad. Several staff members are well known internationally. Currently the group is collaborating with institutions in Germany and potentially in China. The academic staff have been able to obtain external funding to support their research.

The research programme goals and vision for the future are clear and appropriate given the resources available. The potential for increased productivity and reputation appears to be excellent if sufficient university support in filling staff vacancies is available and if the programme can attract high quality PhD candidates interested in carrying out multi-disciplinary research. There are many opportunities for increased funding and collaboration in Europe and internationally. There is also a critical need for individuals who are able to perform effectively in an interdisciplinary environment.

Appendix 1 Discipline Protocol Civil Engineering and Geodesy

Introduction

This research assessment covers the disciplines of Civil Engineering and Geodesy. The Faculty of Civil Engineering and Management of the University of Twente and the Faculty of Civil Engineering and Geosciences of Delft University of Technology, covering amongst others the fields of Civil Engineering and Geodesy, will participate in this research assessment.

The aim of the research in these engineering fields is to perform research of high international standard which in Twente is more application-oriented, multidisciplinary research, based on fundamental, knowledge driven research and in Delft is both fundamental, knowledge-driven and application-oriented. The presence of mono-disciplinary and multidisciplinary research programmes and Research Schools further characterise the research in civil engineering and geodesy. In accordance with the Protocol 1998 the main goals of the quality assessment are to enhance the quality of the individual research programmes and to provide the information for the accountability of the research carried out in the assessment period.

Delineation and required expertise of committee members

Besides a positive attitude towards fundamental and applied aspects of research and the multidisciplinary character of the disciplines of Civil Engineering and Geodesy, the following expertise is required for the members of the review committee:

- Mechanics, Materials and Structures
- Building Engineering
- Infrastructure
- Hydraulic and Geotechnical Engineering
- Water Management
- Geodesy
- Management

The committee will consist of seven members, the chair included. Special attention will be required for the differences in approaches in the sub-disciplines, for example, for the field of geodesy: the geometrical and geothematical area descriptions. If the committee feels the need to do so, external experts may be consulted.

Information for the committee and procedures

The committee is independent and will determine its own method of working, within the framework of Protocol 1998 and this Discipline protocol.

The assessment will be performed on the basis of a self-evaluation report provided by the research programme directors and the faculty. Furthermore, the Committee will have meetings with the programme directors, and if desired by the Committee, other participants in the research programmes (for example, PhD students (AIOs)). In preparation of the meetings the committee will give the topics and the goal of the discussions that will be held with the faculty board and the separate groups during the site visits. A site visit to research groups is required and sufficient time has to be spent on a visit to the facilities.

The assessment will cover the research carried out in the period 1995-1999.

Level of aggregation

A research programme is defined as “a coherent set of research activities having a common mission and being the work of a group of people who generally work together on a daily basis”. For the purpose of this evaluation this will normally be the activities of a group directed or co-ordinated by a chair (leerstoele).

Programme members

The list of programme members in chapter (3) of each programme shall include the following ranks:

- professors (hgl)
- associate professors (uhd)
- assistant professors (ud)
- fellows and others who have attained a PhD

The list will include all members involved in the programme over the assessment period and will also indicate whether members were involved only part of this period.

Research input of academic staff

In the table concerning research input all junior researchers in any stadium of promotion are concerned as AIOs/OIOs; the programme members as mentioned above are concerned as others. In this assessment the input of all personnel will be done on the basis of the actual contribution to the research, but one person cannot be involved in research plus education for more than 1 fte.

Output categorisation

According to the types of publications which are mentioned in “*Assessment of Research Quality: Protocol 1998*, Utrecht, VSNU, 1998,

Appendix 4 (pp. 41-44) the following categories are taken into account:

- PhD theses
- Academic publications divided in journal articles and other academic publications. For the journal articles a distinction is made in refereed and non-refereed articles. Other academic publications include books, chapters and conference-proceedings. A distinction will be made in publications written in an internationally accessible language (English, German or French) and in Dutch. For conference proceedings it is required that the conference attendance was international; no distinction will be made in refereed or non-refereed.
- Professional publications and scientific reports for other parties

The categories “Engineering and Technology Products” and “Citation indices” may be mentioned in Section C (Documentation per programme) under paragraph 12: ‘other indicators of quality and reputation’.

In accordance to these categories the table concerning research output (see *Assessment of Research Quality: Protocol 1998*, Utrecht, VSNU, 1998, appendix 3, Section C, 6. Research output, p.38) should read:

<i>number</i>			1995	1996	1997	1998	1999	total
PhD theses								
academic publications	journal articles	refereed	international					
			Dutch					
	non refereed	international						
		Dutch						
	other acad. publications:		international					
	books, chapters		Dutch					
	conference proceedings							
professional publications			international					
			Dutch					
scientific reports								

A list will be added of PhD theses, academic publications, and patents. For the output category professional publications and reports the number of the publications will suffice.

Further relevant information for this assessment

In the self study report attention can be paid to the following subjects:

- The role of the research programme in the educational programme. This can be done either for the faculty (in part B of the report) or in part C (for each programme).
- Local, national and international co-operation

Appendix 2 Preliminary Assessment Form

Review Committee Civil Engineering and Geodesy
(Please return to the Secretary of the Review Committee before)

Title programme:

Code:

First Reviewer:

Filled in by:

Second Reviewer:

1. Ratings

(Please give your ratings on a 5-point scale, in which: 5 = excellent; 4 = good; 3 = standard; 2 = below standard; 1 = poor.

Note: Start from the assumption that all University research should normally conform to a certain standard. Consider whether each aspect of this programme is above/on/below this standard. The committee report must specify why deviation of the standard is perceived. Your preliminary assessment is only for use in the committee meetings and will not be published in the committee report.)

	1	2	3	4	5
QUALITY					
How do you evaluate the quality with respect to the:					
1. originality of the approach and ideas					
2. significance of its contribution to the field					
3. coherence of the programme					
4. publication strategy in view of the stated mission					
5. prominence of the programme director					
6. prominence of other members of the research group					
7. distribution of published output over the team members					
8. scientific publications (scientific impact)					
9. professional publications					
10. design and software					
Overall assessment of quality level					
PRODUCTIVITY					
Considering number of staff, how do you evaluate the productivity of the programme with respect to the:					
1. number of PhD theses					
2. number of scientific publications					
3. number of professional publications					
Overall assessment of productivity					

	1	2	3	4	5
RELEVANCE					
Considering the stated mission of this programme, how do you evaluate the relevance of the research with respect to:					
1. the advancement of knowledge					
2. the dissemination of knowledge					
3. the implementation of knowledge					
Overall assessment of relevance					
LONG-TERM VIABILITY					
Considering the present status and future developments (if known) of staff and facilities, how do you evaluate the long-term viability of the programme:					
1. in view of the past scientific performance					
2. in view of future plans and ideas					
3. in view of staff age and mobility					
Overall assessment of long-term viability					

2. Draft review

(suggested subjects:

- Short *description* on the research subject, mission, strategy and recent results
- Development and *progress* of the programme/group in the given period
- Appraisal of *publication strategy* and productivity
- Appraisal of the *international position* and reputation
- (international) *co-operation*
- *funding* strategies and results
- *relevance* for users, professionals, society
- potential for the *future*)

3. Questions

(to the Programme Director and/or the Faculty Board)

Appendix 3 List of scores per programme

Legenda²:

Q = quality 5 = excellent
 P = productivity 4 = good
 R = relevance 3 = standard
 V = viability 2 = below standard
 1 = poor

Code	Research Programme	Q	P	R	V
TUD 01	Building Engineering	3	3	3	3
TUD 02	Civil Engineering Informatics	4	3	3	3
TUD 03	Design and Construction Management	3	2	3	3
TUD 04	Fluid Mechanics	5	5	5	5
TUD 05	Geotechnical Engineering	4	4	4	4
TUD 06	Hydraulic Engineering	5	4	5	4
TUD 07	Infrastructure Planning	2	2	2	2
TUD 08	Road and Railway Engineering	4	4	4	4
TUD 09	Transportation Planning and Traffic Engineering	5	5	5	5
TUD 10	Concrete Structures	4	4	4	5
TUD 11	Materials Science	4	4	4	4
TUD 12	Steel and Timber Structures	4	4	4	4
TUD 13	Structural Mechanics	5	5	5	5
TUD 14	Wind Energy and Offshore Technology	3	3	4	4
TUD 15	Hydrology and Ecology	4	3	3	4
TUD 16	Land and Water Management	4	4	4	4
TUD 17	Sanitary Engineering	4	5	4	4
TUD 18	Physical, Geometric and Space Geodesy	4	3	4	4
TUD 19	Mathematical Geodesy and Positioning	5	5	5	5
TUD 20	Photogrammetry and Remote Sensing	3	3	3	4
TUD 21	GIS Technology	3	3	3	4
TUD 22	Geo-Information and Land Development	3	3	3	4
UT 01	Construction Engineering and Management	2	2	3	2
UT 02	Integrated Modelling of Civil Engineering Systems	4	4	4	3
UT 03	Transportation Engineering and Management	4	3	4	4
UT 04	Water Resources Management	4	4	4	4

² For a more elaborate explanation of the aspects of assessment and the ratings see paragraph 1.6

Appendix 4 Curricula Vitae

Jelle Witteveen (Chairman) was Managing Director of TNO Building and Construction Research and Professor of Structural Mechanics at the Faculty of Civil Engineering of Delft University of Technology. He started his career at TNO Building and Construction Research in 1958 and graduated in Civil Engineering from Delft University of Technology (1963). His research interests covered mainly plastic analyses and fire engineering design of steel structures. Whilst maintaining research activities, from 1971 to 1983 he was deputy director, and from 1984 to 1994 managing director of TNO Building and Construction Research. From 1975 to 1997 he was a part-time professor of structural mechanics at the Faculty of Civil Engineering of Delft University of Technology and from 1994 to 1997 scientific director of the Research School for Advanced Studies in Construction. Presently he is a non-executive board member of a company in the construction sector and member of several committees on science and technology of the government and research organizations in the Netherlands and in Sweden. He served as president of the International Council for Research and Innovation in Building and Construction and as vice-president of the European Network of Building Research Institutes. Jelle Witteveen received the Research Medal of the European Convention for Constructional Steelwork for his work on steel structures in fire.

Dieter Fritsch is Professor of Photogrammetry and Remote Sensing at the University of Stuttgart, where he is also Rector and Director of the Institute for Photogrammatry. After studies of Surveying and Geodesy at the University of Applied Sciences at Mainz and the University of Bonn he was Assistant Professor at the Institute of Theoretical Geodesy at the University of Bonn. In 1982 he obtained the Doctor degree from the University of Bonn and was soon thereafter appointed Assistant Professor in the Technical University of Munich, where he habilitated in GIS and Digital Terrain Modelling (1990). During a period of leave from Technical University of Munich in 1989 he was a Visiting Professor at the Federal Polytechnical Institute of Lausanne, Switzerland. Since 1992 he is Full Professor and Director of the Institute for Photogrammatry at the University of Stuttgart. Dieter Fritsch was Dean of the Faculty of Civil Engineering and Surveying Science and Vice-Rector for Education, both at the University of Stuttgart. He was President of the International Society for Photogrammetry and Remote Sensing (ISPRS) Technical Commission IV from 1996 to 2000. Since 1998 he is Editor-in-chief of *Geo-Information Systems*. He has written over 200 publications and 10 textbooks on Statistical Inference, Signal Processing, Photogrammatry, Remote Sensing and GIS.

Patrick Holmes is Professor of Hydraulics in the Department of Civil and Environmental Engineering of Imperial College, London, United Kingdom. He received his Bachelor degree (1960) and his PhD (1963) in Civil

Engineering both from the University of Wales. After that he moved to California to become Research Engineer at the U.S. Navy Civil Engineering Laboratory. He returned to England in 1967 where he was appointed successively a Lecturer, Senior Lecturer and Professor of Maritime Civil Engineering in the University of Liverpool. In 1983 he accepted his current position at Imperial College, where he was Dean of Engineering during the period 1989-1992. Patrick Holmes is Member of the Institution of Civil Engineers, London, a Chartered Engineer and a Fellow of the City and Guilds of London Institute.

Arie Krijgsman was Professor of Structural Design in the Faculty of Architecture at Delft University of Technology from 1982-1999. After a study of Building Engineering he graduated in Civil Engineering from Delft University of Technology. As a partner of ABT Consulting Engineers at Velp and Delft he was involved in the structural design of many outstanding structures for buildings and bridges from 1968-2000. Several of his projects were awarded with national and international awards for steel and concrete structures.

Peter Lansley is Professor of Construction Management in the Department of Construction Management & Engineering at The University of Reading. He graduated in Mathematics (1968), and holds a Masters degree in Statistics and a Doctorate in Construction Management. In 1984, after 14 years at Ashridge Management College as Assistant Director of Research, he joined Reading University, where he became Professor in 1990. He has been Head of Department, Dean of the Faculty of Urban and Regional Studies, Director of Social Science Research, and Pro-Vice Chancellor. His work has been principally concerned with innovation and the management of businesses in the construction industry, through extensive research programmes, consulting assignments, and organisational development interventions.

Daniel P. Loucks is Professor of Civil and Environmental Engineering in the Department of Environmental Engineering at Cornell University. He obtained a BS from Pennsylvania State University (1954), a MF from Yale University (1955), and a PhD from Cornell University (1965). Since 1965 he has been on the faculty of the School of Civil and Environmental Engineering, Cornell University. In 1976 he was appointed Professor of the Department of Environmental Engineering in the School where he teaches and directs research in the application of economic theory and systems analysis methods to the solution of environmental and regional water resources problems. He served as Chair of the Department from 1974 to 1980, and as Associate Dean for Research and Graduate Studies in the College of Engineering from 1980 to 1981. During periods of leave from Cornell, Daniel P. Loucks was, among other things, a Research Fellow at Harvard University, and a Visiting Professor at the Massachusetts Institute of Technology, the University of Adelaide in South Australia, the Aachen University of Technology in Germany. He has served on various committees of the National Research Council of the National Academy of

Sciences, and was a U.S. member of an advisory committee for the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria. Daniel P. Loucks has received several fellowships and numerous national and international awards. Amongst them the Huber Research Prize, the Julian Hinds Award, a Fulbright-Hayes Fellowship, the Senior U.S. Scientist Research Award from the German Alexander von Humboldt Foundation, and the Warren A. Hall Medal from the Universities Council on Water Resources. He was elected to Fellow in the American Society of Civil Engineers in 1983 and to Honorary member in 1998. He was elected to the National Academy of Engineering in 1989.

Hani Mahmassani is the A. Abou-Ayyash Centennial Professor in Transportation Engineering and Professor of Management Science and Information Systems at the University of Texas at Austin, where he is also Director of the Advanced Institute for Transportation Infrastructure Engineering and Management. He specializes in transportation systems analysis and planning, network modeling, econometric techniques, demand forecasting and systems evaluation and decision support models. He received his PhD in Transportation Systems from the Massachusetts Institute of Technology (1982) and his MS in Transportation Engineering from Purdue (1978). He chairs several technical and professional committees in the US and internationally, and is Associate Editor of *Transportation Science*, *Transportation Research C (Emerging Technologies)*, and the *IEEE Transactions on Intelligent Transportation Systems*. He serves on the editorial boards of the major transportation journals. He is a past president of the Transportation Science Section of the Institute for Operations Research and the Management Sciences, and the President of the International Association for Travel Behavior Research. He has published over 140 refereed articles and conference proceedings, and over 100 technical reports. He has served as Principal investigator on over 90 funded research projects sponsored by the National Science Foundation, The Advanced Technology Program, General Motors Research Laboratories, CRAY Research Inc., Texas Department of Transportation, Texas Governor's Office, Capital Metropolitan Transportation Authority, U.S. Department of Transportation, Federal Highway Administration, and served as consultant to several companies and government agencies in the areas of transportation planning, operations, logistics and intelligent transportation systems.

Herbert Mang is Professor of Strength of Materials at the Department of Civil Engineering of Vienna University of Technology and Secretary General of the Austrian Academy of Sciences. After graduating to Dipl.-Ing. (Civil Engineering, 1967) from Vienna University of Technology he obtained the degree of Dr.techn. from TU-Wien (1970) and a PhD from Texas Tech University (1974) as Fulbright Fellow. From 1975 to 1976 he was a Max-Kade Fellow at Cornell University. In 1977 he habilitated at Vienna University of Technology. He was appointed successively Associate Professor in 1979 and Full Professor in 1983 in Vienna University of Technology, where he is also Director of the Institute for Strength of

Materials since 1985. Herbert Mang was Dean of the Faculty of Civil Engineering and Pro-Rector of Vienna University of Technology. He has published 8 books and over 280 papers in scientific journals and conference proceedings. He was elected to Fellow in the American Society of Civil Engineers in 1991, in the International Association for Computational Mechanics in 1998, and in the International Association for Bridge and Structural Engineering in 2001. In 2000 he obtained an honorary doctorate from Cracow University of Technology, Poland. In the same year he was elected to Foreign Member in the Polish Academy of Sciences.

Hans Sünkel is Professor of Mathematical and Numerical Geodesy, Head of the Institute for Space Research of the Austrian Academy of Sciences (AAS) and Vice-Rector (Research) of the Graz University of Technology. He graduated to Dipl.-Ing. Geodesy (1973) and obtained the degree of Dr.techn. (1976) both from Graz University of Technology, Austria. After being a Research Associate in Ohio State University for two years he returned to Graz University of Technology where he habilitated in Numerical Geodesy (1981) and was appointed Full Professor of Mathematical and Numerical Geodesy and Head of Department (1983). From 1987 up to 1998 he was Head of the Institute of Theoretical Geodesy. He has written over 140 scientific publications and gave over 200 scientific presentations in 22 countries. He was Scientific manager of numerous national and international R&D Projects (ESA, EU, AAS, etc.) and member of several national and international Commissions such as European Space Science Committee, ESA Advisory Board for the Satellite Mission GOCE, Executive Committee of the International Association of Geodesy (IAG), and German Geodetic Commission. Hans Sünkel received the W.A. Heiskanen Award and the Grand Medal for Distinguished Services for the Republic of Austria. He was elected to Fellow in the International Association of Geodesy and Distinguished International Research Fellow, Canada.

Appendix 5 List of Abbreviations

AGRS-NL	Dutch Active GPS Reference System
AIO	PhD student
AWT	Advisory Council for Science and Technology Policy
DIOIC	Delft Interdisciplinary Research Centre
fte	Full time equivalent
GIS	Geographic Information System
GPS	Global Positioning System
IHE	International Institute for Infrastructural, Hydraulic and Environmental Engineering
INSAR	SAR Interferometry
KNAW	Royal Netherlands Academy of Arts and Sciences
NWO	Netherlands Research Council
OIO	PhD student financed by NWO
P3BI	Foundation of Public and Private organisations in construction industry for joint research into Processes in planning, development and realisation of Buildings and Infrastructure
SLR	Satellite Laser ranging
TNO	Netherlands Organisation for Applied Scientific Research
TUD	Delft University of Technology
UT	University of Twente
VLBI	Very Long Baseline Interferometry
VSNU	Association of Universities in the Netherlands

